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Research article

A comparison of the sit-and-reach test and the back-saver sit-and-reach test in university students

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Abstract
This study compares the forward reach score, spine and pelvis postures, and hamstring criterion-related validity (concurrent validity) between the sit-and-reach test (SR) and the back-saver sit-and-reach test (BS). Seventy-six men (mean age ± SD: 23.45 ± 3.96 years) and 67 women (mean age ± SD: 23.85 ± 5.36 years) were asked to perform three trials of SR, BS left (BSl), right (BSr), and passive straight leg raise (PSLR) right and left (hamstring criterion measure) in a randomized order. The thoracic, lumbar, and pelvis angles (measured with a Uni-level inclinometer) and forward reach scores were recorded once the subjects reached forward as far as possible without flexing the knees. A repeated measure ANOVA was performed followed by Bonferroni´s post hoc test. Pearson correlation coefficients were used to define the relationships between SR and BS scores with respect to PSLR. In both men and women, the thoracic angle in BS was significantly greater than in SR ($p<0.016$). However, no significant differences were found between the tests in lumbar angle, pelvic angle, and forward reach scores. The concurrent validity of the forward reach score as a measure of hamstring extensibility was moderate in women (0.66–0.76) and weak to moderate in men (0.51–0.59). The concurrent validity was slightly higher in SR than in BS, although no significant differences between the correlation values were observed. There were significant differences in the thoracic angle between the SR and BS, but not in the forward reach score. There was no difference in concurrent validity between the two tests. However, the traditional SR was preferred because it reached better concurrent validity than the BS.

Key words: Hamstring, flexibility, measurement, spine.

Introduction

Several sit-and-reach tests (SRs) are commonly used in health-related and physical-fitness test batteries to evaluate the hamstring and lower back flexibility (Hui and Yuen, 2000). There is little research evidence that any kind of SR adequately measures low-back flexibility. Such field measures are only moderate indicators of hamstring extensibility. However, the SRs are frequently used to evaluate the hamstring muscle extensibility because the procedures are simple, easy to administer, require minimal skills training and are particularly useful in large-scale extensibility evaluation in the field setting. The classical SR was originally selected as a part of the American Alliance for Health, Physical Education, Recreation & Dance (AAHPERD) health-related and physical-fitness protocol, and is often included in standard fitness tests (e.g., EUROFIT: personal fitness tests, President's Challenge) and health-related fitness programs. The SR is a field test which is quick and easy to administer. It provides a moderate indication of hamstring extensibility (Baltaci et al., 2003; Hui and Yuen, 2000; Jackson and Baker, 1986; Liemohn et al., 1994a; Martin et al., 1998). Prudential FITNESSGRAM fitness test (Cooper Institute for Aerobics Research, 1994), however, recommended the back-saver sit-and-reach test (BS). The assessment of BS is conceptually similar to SR, but only one leg is extended against the sit-and-reach box while the other is flexed. The BS appears to be similar to the SR in that it is primarily a test of hamstring extensibility (Patterson et al., 1996) but the BS test is intended to be safer on the spine by restricting the intervertebral flexion, and can also be used to determine symmetry in hamstring flexibility (Liemohn et al., 1994a). Baltaci et al. (2003) recommended the BS because it was reported to be more comfortable than the SR in young females. The selection of SR is based on his criterion-related validity, because the SRs are the indirect measures of hamstring muscle extensibility.

Various studies have analyzed the concurrent validity and reliability of both SR and BS (Baltaci et al., 2003; Hartman and Looney, 2003; Hui and Yuen, 1998; Hui et al., 1999; Jones et al., 1998; Liemohn et al., 1994a; Liemohn et al., 1994b; Patterson et al, 1996; Yuen and Hui, 1998). They reported that the SR and BS are moderately valid indicators of hamstring muscle extensibility with Pearson correlation values ranging from 0.39 to 0.76. However, the above studies only analyzed the differences between forward reach score and concurrent validity, and not the pelvic (hip) and spinal postures. Miñarro et al. (2007) observed significant differences in the thoracic angle between SR and BS. They concluded that the thoracic posture is influenced by the position and administration procedures of SR in both men and women. However, they did not analyze the influence of these differences on the forward reach score.

Theoretically, the flexion of the leg at both the knee and hip joints in the BS rotates the pelvis and reduces the intervertebral flexion (Cailliet, 1988; Liemohn et al., 1994a), although Liemohn et al. (1994b) analyzed the lumbosacral movement and the forward reach score of the BS and SR with an Ady–Hall lumbar monitor, and reported that the amount of spinal movement occurring in both the tests was similar.

Currently, little information is available concerning the spine and pelvic postures of the BS and SR and their

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influence on the forward reach score. The forward reach score does not distinguish between the contributions of the lumbar and thoracic spine and the hip joints during this reaching activity (Cornbleet and Woolsey, 1996). Trunk flexion is a complex movement involving the lumbar, thoracic, and hip flexion, and the position should be considered because the spinal posture may modify the forward reach score.

The choice of the test to be employed is often based on the examiner´s preference, ease of use, professional discipline, or tradition, rather than scientific evidence (Davis et al., 2008). However, the selection of SR or BS test as a measure of hamstring muscle extensibility should be based on the concurrent validity. Since it was stated in an earlier study (Miñarro et al., 2007) that the differences in the lower limbs´ position influences the spinal angles when SRs are employed, it is necessary to establish if these differences have any influence on the forward reach score and spinal posture. Therefore, the purposes of this study were: 1) to compare thoracic angle between BS and SR tests; 2) to compare lumbar angle between BS and SR tests; 3) to compare pelvic angle between BS and SR tests; and 4) to compare the concurrent validity between BS and SR tests with regards to the criterion measure of hamstring extensibility (passive straight leg raise).

Methods

Subject

Sixty-seven women (mean value ± SD, age: 23.85 ± 5.36 years, weight: 59.57 ± 8.54 kg, height: 1.64 ± 0.05 m) and 76 men (mean value ± SD, age: 23.45 ± 3.96 years, weight: 75.37 ± 10.39 kg, height: 1.76 ± 0.07 m) were recruited from a university population. The exclusion criteria were histories of orthopedic problems, such as episodes of hamstrings injuries, fractures, surgery or pain in the spine or hamstring muscles over the past six months. Written informed consent was obtained from the participants prior to the study, and the protocol was approved by the Ethics and Research Committee of the University.

Procedures

Prior to measurements, the skin levels of T1, T12, L5, and posterior superior iliac spines were located by palpation with the subjects standing upright by using the protocol described by Chen et al. (1997) and Miñarro et al. (2007). The position of the skin levels was marked on the skin surface with a pencil. The spinal process of the first thoracic vertebra was localized by palpating the spinal process of the seventh cervical vertebra and counting down the spinous process from there. The spinous process of the 12th thoracic was located so as to differentiate the degree of thoracic and lumbar spinal angles. By palpating the 12th rib and following it up to the spine, we were able to localize the T12 spinal process. The spinal process of the L5 was identified by detecting the L4 at the level of the iliac crests and counting down the spinous process from there.

Before testing, the subjects performed standardized static stretching exercises for 5 min on the lower back and hamstring muscles. Exercises included a seated lower-back stretch (sitting in a chair with the knees spread apart, bend forward towards the floor), double-knee-to-chest stretch (lay supine on the floor with both knees bent, the hands around both knees, pulling them firmly to the chest), unilateral supine hamstring stretch (lay supine on the floor with the stretching leg on the wall and the other leg flat on the floor, with distance from the wall adjusted so a hamstring stretch was perceived), and unilateral standing hamstring stretch (stand on one leg while placing the stretching leg forward on an elevated surface and simultaneously bending forward at the hip without flexing the spine). Each exercise was done twice to the point of moderate discomfort and held for 15 s. We used the pre-stretching exercises because all the tests required a great hamstring tension stimulus. Immediately following the stretching procedures, the subjects were asked to perform three trials of passive straight leg raise (PSLR) (left and right leg), SR, and BS (left and right leg) in a randomized order and the average of each test was used for the data analyses. The subjects were allowed to rest for 5 min between tests. All measurements of each subject were conducted on the same session by two testers with the help of a lab assistant. Tester 1 measured the spine and pelvic postures, while tester 2 measured the forward reach score. Both the testers were physical therapists with 10 years of experience in the measurement of spinal curvatures. During testing, the subjects were asked to remove their shoes. Testing room temperature was kept at 25ºC.

Thoracic, lumbar and pelvic angles were recorded to the nearest degree with a Uni-level inclinometer (ISOMED, Inc., Portland, OR) when the subjects reached forward maximally. The inclinometer is a hand-held, round, and fluid-filled disk with a weight-gravity pendulum indicator that remains vertically oriented. This disk is calibrated at 1º intervals over the 360º range. The inclinometer measured the total orientation of a line in a vertical plane (the line being formed by two vertebral reference points) at the end of the reach. Earlier reliability studies showed that the intra-rater correlation coefficients of inclinometer ranged from 0.73 to 0.88 (Saur et al., 1996). Comparison of the radiographic and inclinometer measurements of sagittal posture of the thoracic and lumbar spine generally showed a moderate to high correlation (r=0.73–0.98) (Mayer et al., 1984; Saur et al., 1996).

The inclinometer was placed at T1 and the dial was set at 0º to measure the degree of thoracic angle when the subject reached forward maximally (Figure 1). The inclinometer was later positioned at T12, obtaining instant reading of the thoracic angle. Subsequently, the inclinometer dial was placed again at 0º at T12 to measure the degree of the lumbar angle and then repositioned at L5, to obtain an instant reading of the lumbar angle.

The pelvic angle was defined as the inclination angle of the sacrum with respect to the horizontal plane at the point of maximal forward reach. 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. The pelvic angle was the maximum angle read from the inclinometer at the point of maximum trunk flexion. The inclinometer was set so that 90º represented the vertical position. Thus, a lower angle reflects an anterior pelvic tilt while a greater angle reflects a posterior pelvic tilt.

Figure 1. Reaching position of the back-saver sit-and-reach test with the inclinometer placed at T1.

Measurements

To standardize the measurement scale of SR and BS, a standard meter rule was placed on the sit-and-reach box for each test, with the reading of 23 cm in line with the heel position of each test. Reaches short of the toes were recorded as negative forward reach scores, and reaches beyond the toes were recorded as positive forward reach scores. The forward reach scores were recorded in centimeters to the nearest 0.5 cm using the scale on the box.

Sit-and-reach test

The subjects sat with their feet approximately hip-wide against the testing box. They kept their knees extended and placed the right hand over the left, and slowly reached forward as far as they could by sliding their hands along the measuring board.

Back-saver sit-and-reach test

The test was administered as described in the Prudential FITNESSGRAM test manual (Cooper Institute for Aerobics Research, 1994). The subjects sat at the SR box and fully extended one leg so that the sole of the foot was flat against the end of the box. The subjects bent the other leg so that the sole of the foot was flat on the floor with the knee and hip at 90º and 45º, respectively. They placed the right hand over the left, and slowly reached forward as far as they could by sliding their hands along the measuring board. The BS was administered with each leg extended in a counterbalanced order to ensure that asymmetry would not bias the test results.

Hamstring criterion

The passive straight leg raise (PSLR) test was used as the criterion measure of hamstring extensibility. While the subject was in a supine position and pelvis fixed in a neutral position, the inclinometer was placed over the distal tibia and the free hand was placed over the knee to keep it straight. The subject's leg was lifted passively by the tester into a hip flexion, until the subjects reported pain within their hamstring or when the restricted hip flexion was detected by the tester or when the pelvis underwent posterior pelvic tilt. An inclinometer was used to control the posterior pelvic tilt. The other knee remained straight during the leg raise. The ankle was fixed in plantar flexion throughout the test to avoid adverse neural tension (Gajdosik et al., 1985). The PSLR angle was the maximum angle read from the inclinometer at the point of maximum hip flexion. Angles were recorded at the nearest degree for each leg The average of the three trials on each side was used for subsequent analyses.

Statistical analyses

Descriptive statistics including means and standard deviations were calculated for all the variables. Internal consistency reliability for all the variables was determined using intraclass correlation coefficients (ICC 3,1), and the associated 95% confidence intervals, according to the formula described by Shrout and Fleiss (1979). The standard error of measurement (SEM) was calculated using the formula $SEM = SD * \sqrt{1 - R}$. The minimal detectable change at the 95% confidence level ($MDC_{95\%}$) was calculated using the formula $MDC_{95\%} = SEM * 1.96 * \sqrt{2}$. A two-factor ANOVA (gender × tests) with repeated measures on the second factor was used for each dependent variable: thoracic angle, lumbar angle, forward reach score, and pelvic angle. The level of significance was set a priori at $\alpha = 0.05$. If the main effects were significant, Bonferrroni's correction post hoc test was performed to reduce Type I error. The new p level was set at $p < 0.016$. To examine concurrent validity a Pearson Product Moment Correlation was conducted between each forward reach score and the criterion measure of hamstring extensibility (PSLR). The *t*-tests for dependent correlations (Glass and Hopkins, 1984) were used to test the statistical differences between the correlation values of the SR and the BS right and left with respect to PSLR. All the analyses were carried out using SPSS 15.0 for Windows.

Results

The ICC 3,1, SEM and $MDC_{95\%}$ for PSLR, forward reach score, lumbar angle, thoracic angle, and pelvic angle in both SR and BS are presented in Table 1.

The mean forward reach score, thoracic angle, lumbar angle, pelvic angle in the SR and BS (left and right leg), and the PSLR angle (left and right leg) are presented in Table 2. The two-way ANOVA revealed significant differences in the main effects of thoracic angle among the SRs ($p < 0.05$). Post hoc comparisons with Bonferroni´s correction showed that the subjects reached significantly lower thoracic angles in the SR than in the BS left and right ($p < 0.016$) for both men and women, with difference values ranging from 2º to 4º. The $MDC_{95\%}$ indicated that changes between 6º and 11º would be required to reflect real change in thoracic angle. No significant differences were observed between the lumbar angle, pelvic angle and forward reach score.

Women showed significantly lower mean values of thoracic angle and pelvic angle, and greater mean values of PSLR and forward reach score, when compared with men on SR and BS left and right ($p < 0.001$). However, no differences were observed between genders with respect to the lumbar angle (Table 2).

The correlation values between the PSLR and SR were higher, although no significantly different, than

Table 1. Intraclass reliabilities (single trial) with 95% confidence intervals, standard error of measurement and minimal detectable change for all measured variables.

Variable	Men				Women			
	ICC	.95 CI	SEM	MDC	ICC	.95 CI	SEM	MDC
Sit-and-reach test								
Thoracic	.92	.91-.94	2.3	6	.93	.92-.94	4.0	11
Lumbar	.90	.88-.93	2.5	7	.90	.89-.93	2.5	7
Pelvic	.94	.90-.96	2.2	6	.93	.90-.96	3.4	9
Forward reach score	.97	.96-.98	1.4	4	.98	.97-.99	1.3	4
Back-saver-sit-and-reach right								
Thoracic	.91	.89-.93	2.7	7	.93	.91-.95	3.2	9
Lumbar	.89	.84-.93	2.6	7	.91	.89-.93	2.1	6
Pelvic	.93	.90-.95	2.4	7	.92	.89-.94	3.3	9
Forward reach score	.97	.96-.98	1.2	3	.97	.96-.98	1.4	4
Back-saver-sit-and-reach left								
Thoracic	.92	.91-.94	2.3	6	.94	.93-.96	2.7	7
Lumbar	.90	.88-.91	2.5	7	.93	.89-.96	2.4	7
Pelvic	.92	.89-.94	2.5	7	.94	.90-.96	2.7	7
Forward reach score	.96	.93-.98	1.4	4	.97	.95-.98	1.4	4
Passive straight leg raise								
Right	.90	.87-.92	2.8	8	.93	.90-.95	4.0	11
Left	.91	.88-.93	3.0	8	.91	.88-.93	4.2	12

ICC: intraclass coefficient correlation; MDC: minimal detectable change; SEM: standard error of measurement.

those between the PSLR and BS. The correlation comparison between genders showed higher r-values in women (Table 3).

Table 2. Mean (± standard deviations) values for the score (cm), thoracic angle, lumbar angle, pelvic position, and straight leg raise (degrees) in men and women.

Variables	Men (n=76)	Women (n=67)
Thoracic angle		
Sit-and-reach	70 (8)	59 (15)
Back Saver-right	72 (9) *	63 (12) *
Back Saver-left	72 (8) *	62 (11) *
Lumbar angle		
Sit-and-reach	28 (8)	30 (8)
Back Saver-right	27 (8)	29 (7)
Back Saver-left	27 (8)	29 (9)
Pelvic position		
Sit-and-reach	105 (9)	92 (13)
Back Saver-right	106 (9)	93 (12)
Back Saver-left	107 (9)	93 (11)
Score		
Sit-and-reach	23 (8)	28 (9)
Back Saver-right	23 (7)	27 (8)
Back Saver-left	22 (7)	28 (8)
Straight leg raise		
Right	72 (9)	85 (15)
Left	72 (10)	85 (14)

* $p < 0.016$ respect to sit-and-reach test.

Discussion

The principal results of this study demonstrated that there were significant differences in the thoracic angle between the SR and BS, with difference values ranging from 2º to 4º. The analysis of the $MDC_{95\%}$ confirms that the differences found in this study can be considered insignificant. The $MDC_{95\%}$ is the amount of change that is likely to be greater than measurement error, which has been defined as "true change". The $MDC_{95\%}$ values indicate that changes of greater than 6º between tests would be required to reflect real change in thoracic angle. A change angle less than this may occur as a result of measurement error associated with measurement of the spinal posture on separate occasions. For this reason, the difference between both tests seemed to be clinically irrelevant.

Table 3. Correlation (P-Pearson) between passive straight leg raise (left and right) with respect to pelvic position and score in the sit-and-reach and the back-saver sit-and-reach (left and right leg) tests in men and women.

	Men (n=76)		Women (n=67)	
	Passive straight leg raise		Passive straight leg raise	
	Left	Right	Left	Right
Pelvic position				
Sit-and-reach	.52 *	.59 *	.69 *	.64 *
Back-saver left	.47 *	—	.55 *	—
Back-saver right	—	.49 *	—	.51 *
Score				
Sit-and-reach	.56 *	.59 *	.75 *	.76 *
Back-saver left	.53 *	—	.70 *	—
Back-saver right	—	.51 *	—	.66 *

* Correlation is significant at the 0.01 level.

To date, only Liemohn et al. (1994a) and Miñarro et al. (2007) had compared the spinal posture between SR and BS. In line with the study of Miñarro et al. (2007), our data show that the thoracic angle was greater in BS than in SR for both men and women, probably owing to the greater unilateral hip flexion of BS (the sole difference in procedure between SR and BS). Also, the greater thoracic angle in the BS could be because of a more posterior position of the shoulder, due to the lower anterior pelvic tilt and lumbar angle (although there were no significant differences with respect to the SR), when the maximal trunk flexion is reached. However, the differences in the thoracic angle between SR and BS were not large enough to surpass the $MDC_{95\%}$ and could be attributable to measurement error.

The BS is intended to be safer on the spine. Cailliet (1988) assumed that stretching one hamstring at a time, by having the other leg flexed, protects the lower back by avoiding excessive flexion of the lumbosacral spine.

Liemohn et al. (1994a) indicated that the flexion of one extremity at both the knee and hip joints posteriorly rotates the pelvis which reduces the turning moment of the trunk and theoretically decreases the intradiscal pressures. Hui and Yuen (2000) postulated that the involvement of the adductor and the gluteus muscle group of the bent leg may limit the forward stretch movement. Liemohn et al. (1994b) analyzed the lumbosacral movement and the forward reach score of the BS and SR with an Ady–Hall lumbar monitor, and reported that the amount of spinal movement occurring in both the tests was similar. Our results of lumbar angle are in agreement with Liemohn et al. (1994b). These data confirm that the position of lower limbs in the BS does not influence the pelvic and lumbar postures when maximal trunk bending with extended knees is executed.

The forward reach score is the sum of anthoropometric factors, scapular abduction, spine and hip flexion. The forward reach scores between SR and BS were not significantly different. The more posterior pelvic tilting of the pelvis together with a lower lumbar angle (although no significant differences were detected) and a greater thoracic angle in BS with respect to SR explained why that the forward reach score was not different between these tests.

There are some studies that have examined the concurrent validity of both SR and BS with respect to straight leg raise (criterion measure of hamstring extensibility). Several studies have found a moderate correlation between forward reach score and PSLR (Baltaci et al., 2003; Hartman and Looney, 2003; Hui and Yuen, 2000; Hui et al., 1999; Liemohn et al., 1994a; Patterson et al, 1996). Our correlation values were moderate in women (0.66–0.76) and weak to moderate in men (0.51–0.59). The correlation values between the PSLR and SR were higher than those between the PSLR and BS for both men and women, although no differences between the correlation values were observed, which is in agreement with earlier researches carried out in adults (Baltaci et al., 2003; Yuen and Hui, 1998), although other studies have found similar correlations between the SR and BS in young adults (Hui and Yuen, 2000; Hui et al., 1999; Liemohn et al., 1994a) and children (Hartman and Looney, 2003). These differences may be related to PSLR measurement. Cameron et al. (1994) stated the necessity of consistency of method when performing and interpreting the PSLR test.

Our results showed greater pelvic angles in the BS than in the SR in both men and women, although no significant differences were found between the tests. The greater posterior pelvic tilting in the BS is probably related to the hip position of the non-evaluated leg. As the hamstring muscles have their origin at the ischial tuberosity, the pelvic angle could provide a better reflection of the hamstring muscle extensibility. In theory, the pelvic angle is influenced only by the hamstring muscle extensibility, whereas the forward reach score is influenced by the contributions of the spine posture and anthropometric factors, which could decrease their validity as a measure of the hamstring muscle extensibility. Davis et al. (2008) examined the concurrent validity of the pelvic angle and the PSLR test, and reported a correlation of 0.50. The correlations between the pelvic angle and the PSLR test in our investigation were observed to range from 0.47 to 0.59 in men and from 0.51 to 0.69 in women. The correlation values between the PSLR and the pelvic angle were slightly lower than between PSLR and forward reach score in men and women for both SR and BS. Cornbleet and Woolsey (1996) observed a significant correlation between the PSLR and the pelvic posture in children (r = 0.76), and suggested that both the forward reach score and pelvic angle reflect the hamstring muscle extensibility. They believed that the use of the inclinometer to measure the pelvic angle as an indicator of hamstring muscle extensibility during SR is simple and offers reliable measurements which are not influenced by the anthropometric factors. However, our results showed that the pelvic angle reached similar or reduced concurrent validity as measure of hamstring extensibility than the forward reach score. As the forward reach score showed a slightly greater correlation than the pelvic angle with respect to the PSLR and also given its easier assess, we recommend this type of measure for an evaluation of a large numbers of subjects. However, the PSLR or knee extension tests are preferred to the SR or BS because they provide a more specific and direct measure of hamstring extensibility.

Gender was included as a between-subjects factor, because earlier studies observed some differences between genders with respect to spine posture (López-Miñarro et al., 2008; Miñarro et al., 2007; Rodríguez-García et al., 2008), forward reach score (Davis et al., 2008; Hui and Yuen, 2000; Hui et al., 1999; Liemohn et al., 1994a; Liemohn et al., 1994b; López-Miñarro et al., 2008; Patterson et al., 1996; Rodríguez-García et al., 2008) and concurrent validity (Hui and Yuen, 2000; Hui et al., 1999; López-Miñarro et al., 2008; Minkler and Patterson, 1994; Patterson et al., 1996; Rodríguez-García et al., 2008). The forward reach score, PSLR, and pelvic angle were greater in women ($p < 0.001$) but the thoracic angle was lower ($p < 0.001$). Gajdosik et al. (1994) reported that reduced hamstring extensibility was associated with the decreased range of motion flexion of the pelvis and lumbar angle and the increased flexion of motion of the thoracic angle. The concurrent validity of both SR and BS in men is compromised, and this may be related to lower hamstring extensibility in men. Hence, other tests should be applied to evaluate the hamstring extensibility in men. Davis et al. (2008) compared several tests (including SR) and recommended that researchers, clinicians, and strength and conditioning specialists adopt the knee extension angle as a measure of hamstring extensibility.

Some studies indicated that arm–leg length discrepancies (Hoeger et al., 1990; Hopkins and Hoeger, 1992) and shoulder and scapula flexibility may play a role in allowing some individuals to achieve higher forward reach scores on SR and modify the concurrent validity. However, other studies found little association between anthropometric characteristics and forward reach score (Hui et al., 1999; Simoneau, 1998). In our study, the same subjects were evaluated in both SR and BS to demonstrate that the relationship between those factors cannot affect the comparison between the results of both the tests. Hoeger et al. (1990) indicated that the SR scores of individuals with short arms and long legs were lower than those with long arms and short legs. We did not measure the anthropometric characteristics of the subjects. However, future studies should attempt to determine the influence of arm–leg length discrepancies in the concurrent validity of the SR and BS with respect to straight leg raise.

This study has several potential limitations. First, the skin levels of T1, T12, L5, and posterior superior iliac spines were palpated and marked when the subjects were standing, and the marks moved upwards during spinal flexion. Therefore, the external measurement may not reflect the true intervertebral movement because of skin-movement error. However, as the subjects were lean young adults, the spinal process of C7 and T1 were easily identified when they the reached maximal trunk flexion. To control the skin movement during trunk flexion at T12 and L5 levels, the upper leg of the inclinometer was situated in contact with the mark. Second, this study involved college-aged subjects, which limits the external validity of the results. Since the hamstring extensibility and spinal posture are different among different age groups, additional studies are needed for children, middle-aged and older adults.

Conclusion

Significant differences were only observed in the thoracic angle between SR and BS. However, these differences were clinically insignificant because may be related to measurement error. Relatively large changes in thoracic angle are required to be confident true difference has occurred. No significant differences were found in the forward reach score or concurrent validity between SR and BS. The traditional SR showed a slightly (but no significant) higher correlation value than the BS with respect to the PSLR test and pelvic angle, although the values of men were weak to moderate. Practitioners may employ the traditional SR over the BS because the SR reaches better hamstring concurrent validity in men and women and the protocol of measure is easier. However, if an individual evaluation of the right and left leg is required and the BS is used, then we recommend interpreting the results with caution, because its concurrent validity is weak to moderate, especially in men.

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Key points

- Previous studies have analyzed the validity of sit-and-reach and back-saver sit-and-reach tests as criterion measures of hamstring muscle extensibility. The differences in the position of lower limbs between both the tests could influence the spinal and pelvic angles and forward reach score.
- Forward reach scores, lumbar and pelvic angles showed no significant differences between the tests, while lower thoracic angle was found in the sit-and-reach. However relatively large changes in thoracic angle were required to be confident true difference had occurred.
- The sit-and-reach test is the preferred test over the back-saver sit-and-reach as measure of hamstring muscle extensibility. The concurrent validity of sit-and-reach and back-saver sit-and-reach in men is compromised, and hence, other tests should be considered to evaluate the hamstring extensibility.

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