ORIGINAL ARTICLE

Comparison of three different sit and reach tests for measurement of hamstring flexibility in female university students

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Background: The sit and reach test is the most common flexibility test used in health related fitness test batteries.
Objective: To examine and compare three different sit and reach tests as a measure of hamstring flexibility in 102 female students.
Method: The traditional sit and reach test, the chair sit and reach test, the back saver sit and reach test, and passive straight leg raise were administered in three trials to all 102 students (mean (SD) age 22 (1) years) on the same day.
Results: A Pearson correlation coefficient analysis was significant ($p<0.01$) for the traditional sit and reach test with back saver sit and reach test and flexibility of hamstrings ($r = 0.45$ and 0.65 for left and right legs, and 0.63 and 0.53 for left and right legs respectively). Also, the back saver sit and reach test for the left ($p<0.01$) and right ($p<0.05$) leg was significantly associated with hamstring flexibility ($r = 0.37$ and 0.25 for the left leg and 0.50 and 0.44 for the right leg respectively).
Conclusion: The results indicate that the back saver sit and reach test produces reasonably accurate and stable measures of hamstring flexibility. Moreover, it appears that this test is a safe and acceptable alternative to the traditional and chair sit and reach tests as a measure of hamstring flexibility in young women.

The sit and reach (SR) test is a field test used to measure hamstring and low back flexibility.[1] This test is present in most health related fitness test batteries because it is believed that maintaining hamstring and low back flexibility may prevent acute and chronic musculoskeletal injuries and low back problems, postural deviations, gait limitations, and risk of falling.[2]

Many studies on the validity and reliability of SR test protocols have been reported, and a number have been proposed.[3–6] The assumed validity of the SR test is based on a logical analysis of its requirements. However, Jackson and Baker[7] reported a study that examined the relations between the SR test and criterion measures of hamstring and low back flexibility in girls of 13–15. They found validity coefficients of $r = 0.64$ between the SR test and a criterion measure for hamstring flexibility, and $r = 0.28$ when compared with a criterion measure for low back flexibility.

All SR test protocols yield moderate validity for hamstring flexibility and poor validity for lower back flexibility.[8] The most common assumption when interpreting SR flexibility test results is that subjects with better scores possess a higher degree of trunk and hip flexibility than those with lower scores.[9] Chair sit and reach (CSR) measures have been found to be highly reliable for both male and female participants ($0.92<0.96$),[3] and so have back saver sit and reach (BSSR) measures (0.99).[4] Previous studies indicate that reliability estimates for the standard SR are consistently high ($0.96<0.99$).[7 10 11]

There have been some studies[12–15] into the relation between flexibility as measured by the SR test and leg length, standing reach, reach length, and head position during the test.

Although the SR, BSSR, and CSR are generally considered acceptable field test measures of hamstring flexibility for most age groups, there are no studies of which is the best technique.

The twofold purpose of this study was to (*a*) compare the three SR tests, and (*b*) evaluate their use as a criterion (goniometer) measure of hamstring flexibility.

MATERIALS AND METHODS

Participants

A total of 102 female university students (age range 20–24 years) volunteered to participate. The criteria for inclusion were no musculoskeletal limitations and low back pain that would limit their performance in these tests, and that they agreed to sign a statement of informed consent.

Procedure

Testing took place in the exercise room at the School of Physiotherapy and Rehabilitation, Hacettepe University. Before testing, all participants performed a three minute warm up and static stretch routine, emphasising the lower body. Immediately after the stretching, the flexibility tests were performed in a counterbalanced design. All tests were assessed on the same day for each student. The participants were allowed to rest for 20 minutes between tests. One physiotherapist was responsible for each test.

The four physiotherapists were unaware of scores received on the CSR test, SR test, BSSR test, and goniometric measurement of hamstring flexibility.

Both the right and left leg scores were used for the CSR, BSSR, and measurement of flexibility. After a demonstration of each test, one practice trial and three test trials were performed for each of the measures. Participants were reminded to exhale as they were bending forward, to avoid bouncing or rapid forceful movement, and never to stretch to

Abbreviations: SR, sit and reach; CSR, chair sit and reach; BSSR, back saver sit and reach

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Table 1 Flexibility scores for participants

	Mean	SD
Chair sit and reach (cm)		
Right	–8.3	9.9
Left	–8.2	9.9
Sit and reach (cm)	6.9	7.8
Back saver (cm)		
Right	–6.2	5.4
Left	–5.7	5.3
Goniometer (°)		
Right	76.5	9.5
Left	75.3	9.8

the point of pain. The average of three test trials was used for all tests. All measures were performed on the same day, and all tests were conducted with the participants wearing their shoes.

Measures

CSR test

After a demonstration, participants sat on a folding chair (seat 40 cm high) and moved forward until they were sitting near the front edge. The chair was placed against a wall so that it would remain stable throughout the test. Participants were asked to extend their preferred leg in front of their hip, with the heel on the floor and foot dorsiflexed, and bend the other leg so that the sole of the foot was flat on the floor about 15–30 cm to the side of the body's midline. With the extended leg as straight as possible and hands on top of each other with palms down, participants were to "slowly bend forward at the hip joint, keeping the spine as straight as possible and the head in normal alignment with the spine". Participants were instructed to reach down the extended leg in an attempt to touch the toes. A static position was held for two seconds while the physiotherapist (SG) recorded the "reached score" using a 40 cm ruler positioned parallel to the lower leg. The middle of the toe at the end of the shoe represented a "zero" score. Reaches short of the toes were recorded as minus scores, and reaches beyond the toes were recorded as plus scores.

SR test

The SR test was performed using the procedures outlined in the ACSM manual.[2] A standard SR box was placed on the floor, by placing tape at a right angle to the 38 cm mark. The participant sat on the floor with shoes on, and fully extended one leg so that the sole of the foot was flat against the end of the box. She then extended her arms forward, placing one hand on top of the other. With palms down, she reached forward sling hands along the measuring scale as far as possible without bending the knee of the extended leg. Throughout testing, the physiotherapist (NU) checked to ensure that the heel remained at the 45 cm mark. Three trials were performed on one side; then the participant changed leg position and repeated the procedure on the other side. The average of the three trials on each side was used for subsequent analyses.

BSSR test

The procedures for the BSSR test were similar to those described in the Prudential FITNESSGRAM test manual (Cooper Institute for Aerobics Research).[16] The test was administered using a Lafayette Flexibility tester (SR box). The participant 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. She then bent the other leg so that the sole of the foot was flat on the floor and 7–10 cm to the side of the straight knee. With the extended leg as straight as possible, hands on top of each other (tips of the middle fingers even), and palms down, the participant slowly reached forward sliding the hands along the box scale as far as possible. The physiotherapist (AB) recorded the average of the three trials on each leg.

Goniometric measurement

The goniometric measurement of hamstring flexibility was administered by one experienced physiotherapist (VT) after the other three tests had been completed. Following procedures outlined by the American Academy of Orthopaedic Surgeons[17] and Kendall *et al*,[18] she used a goniometer to measure hamstring flexibility during a passive straight leg raise. This test was selected because of its prevalent acceptance as a criterion measure for hamstring flexibility and its high reliability ($0.95<0.99$).[3 4 7 10] The axis of the goniometer was aligned with the axis of the hip joint. The tester positioned the stationary arm in line with the trunk and placed the moveable arm in line with the femur. With the knee held straight, the participant's leg was moved passively into hip flexion until tightness was felt. At that point, the physiotherapist (VT) read the goniometer in degrees of motion. Three trials were performed on each leg, and the average was used for analysis. Scores were recorded to the nearest degree for both legs.

Data analysis

Pearson correlation coefficient analysis was used to determine the relation between the CSR, SR and BSSR tests and the criterion goniometer measurement. Ninety five percent confidence intervals were computed for all correlation coefficients. Statistical Package for Social Sciences (SPSS) MS Windows Release 8.0 (SPSS Inc) was used for the statistical analysis.

RESULTS

The 102 female students had a mean (SD) age of 22 (1.46) years, height of 168.3 (8.9) cm, and weight of 59.7 (11) kg. Table 1 gives their flexibility characteristics.

Correlation coefficients were calculated for the three different SR tests to provide reliability estimates (table 2). The correlation between the hamstring flexibility values for the right

Table 2 Intercorrelations of chair sit and reach, sit and reach, and back saver sit and reach tests with goniometer measured flexibility in all participants (n = 102)

	CSRL	CSRR	SR	BSSRL	BSSRR	GML	GMR
CSRL		0.98**	0.23*	–0.03	0.14	0.22*	0.16
CSRR			0.23*	–0.02	0.17	0.21*	0.16
SR				0.45**	0.65**	0.63**	0.53**
BSSRL					0.66**	0.37*	0.25*
BSSRR						0.50**	0.44**
GML							0.80**

**Correlation is significant at the 0.01 level (two tailed).
*Correlation is significant at the 0.05 level (two tailed).
CSRL, Chair sit and reach, left; CSRR, chair sit and reach, right; SR, sit and reach; BSSRL, back saver sit and reach, left; BSSRR, back saver sit and reach, right; GML, goniometric measurement, left; GMR, goniometric measurement, right.

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and left leg was 0.80, therefore the degree of range of motion for each leg was averaged for each subject to provide one value for hamstring flexibility.

DISCUSSION

Although the CSR, SR, and BSSR tests are the most commonly used field measures of hamstring flexibility in current fitness test batteries, the SR and BSSR tests have inherent limitations for adults with low back problems or who have difficulty sitting on a level surface with legs extended.[7 8 13] Therefore, the CSR test was proposed as an alternative for assessing hamstring flexibility in elderly people.[3]

The purpose of this study was to determine the relations between the three SR tests and hamstring flexibility because the test is used as a measure of hamstring flexibility in young females. The test protocols for the criterion measures were taken from a study in which their reliability and validity were demonstrated.[17]

Our analyses indicated that the traditional SR and BSSR tests were highly related to hamstring flexibility. In contrast, the CSR test was not related to hamstring flexibility for either the right or left leg ($r = 0.22$ and 0.21 respectively). These findings show that both SR and BSSR tests are valid for measuring hamstring flexibility. The CSR test detected individual differences in the flexibility of hamstrings of these female university students.

These results support the findings of Jackson and Baker[7] and Chung and Yuen.[6] However, they concluded that hamstring flexibility can only be measured by the traditional SR test, but we have provided evidence that the BSSR test can be used instead of the traditional SR test in young female subjects. From multiple regression analysis, Jackson and Langford[10] suggested that the combination of flexibility in both hamstrings and lower back contributed to the reported variation in test scores. However, testing subjects of a wide age range, as was done by Jackson and Langford, is questionable. Jackson and Baker[7] and Jackson and Langford[10] reported validity coefficients for the SR test ranging from 0.64 to 0.88 in studies involving teenage and middle aged participants respectively. Also, Patterson *et al*,[4] in a study involving 11–15 year olds, reported fairly comparable BSSR coefficients for male participants (left leg $r = 0.68$; right leg $r = 0.72$), but somewhat lower values for female participants (left leg $r = 0.51$; right leg $r = 0.52$). The low CSR reliability values for the young women in this study were not similar to the SR and BSSR values reported in other studies, with r coefficients for left and right leg in all cases consistently being 0.23 and 0.16 respectively. No participants were eliminated because of their inability to perform the CSR test. Also, because of our emphasis on careful checking of the participants in this study, none fell backwards during the test or were in an incorrect position. No injuries occurred during CSR testing. Careful monitoring is recommended when assessing frail participants or those with balance problems.

Although the SR tests do not satisfactorily measure lower back flexibility and are only moderately valid measures of hamstring flexibility, they are still the only field tests that are practical and easy to administer. Moreover, Jackson *et al*[8] reported that the SR test was not related to reported lower back pain in either a cross sectional or prospective sample of adults. Evidence of the relation between hamstring flexibility or lower back flexibility and lower back health is not documented. Future studies are needed to explore the influence of hamstring flexibility on lower back health. The need to develop a more practical field test with improved validity for hamstring and lower back flexibility is apparent.

Take home message

The back saver sit and reach test is a better test than the others because of the similar criterion related validity in women. It is reported to be the most comfortable of the three sit and reach protocols.

In conclusion, the criterion related validity of all SR protocols appears to be similar. Practitioners should use the BSSR test with caution if flexibility of the lower back is the goal of the measurement process. It also eliminates excessive posterior compression of the vertebral disk when performing a single leg reach. In addition, because the reliability of SR tests is very high, one measurement seems to be sufficient to ensure accuracy when warm up stretching and practice are allowed.

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