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Normalizing Scores of the Modified Back-Saver Sit-And-Reach Test in Middle School Boys

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Abstract. Studies have shown that the modified back-saver sit-and-reach test is the best protocol for hamstring flexibility assessment in adolescents. Although, the MBS incorporated the advantages of other protocols, it does not consider limb length differences. This study was designed to examine the role of limb length on MBS score and to determine the need for normalization.
210 healthy boys, ages 12-18 years, performed 3 trials of the MBS test on the right and left sides. All anthropometric characteristics were measured prior to MBS test. A significant correlation($p<.05$) was found between MBS and anthropometrical characteristics. Among them, Arm span has strongest correlation with MBS and explained the greatest of shared variance of the MBS test. Thus, Normalization was performed by dividing each MBS test by a participant's arm span. Using raw score, there were significant differences between height, BMI, Arm length, Leg length and Trunk length groups in both of the right and left MBS($p\leq.05$), however, No significant differences between these groups were found in MBS after normalization.
In conclusion, when using the MBS test for experimental or clinical purposes, flexibility score should be normalized to arm span to allow for a more accurate comparison of performance among young boys.

Keywords: Modified back-saver sit-and-reach, hamstring flexibility, limb length, arm span, normalization

1. Introduction

Flexibility is recognized as an important component of physical fitness (Minkler et al, 1994). A lack of flexibility is associated with problems in executing and sustaining motor activities in daily life. For example, muscular low back pain may be caused by poor low back/hamstring muscle flexibility (Koen et al, 2003). The sit-and-reach test (SR) was developed to measure hamstring and lower back flexibility. This technique has been used extensively in exercise science laboratories, physical education classes, and commercial fitness centers (Holt et al, 1999). Most SR tests include several varieties of a two-leg floor, raised platform or chair sit-and-reach with or without a box (Koen et al, 2003). Regardless of the minor differences in administration procedures, participant postures, and the equipment used in various SR protocols, the literature agreed that SR tests produced moderate validity in hamstring flexibility assessment but poor validity as a measure of lower back flexibility (Hui et al, 1999). Each protocol possesses unique advantages and disadvantages as compared to other protocols (Hui et al, 2000). The advantages of Classical sit-and-reach test (CSR) are that the procedures are simple, easy to administer, and require minimal skills training. However, a specially constructed box is required. The advantage of the V sit-and-reach test (VSR) over the CSR is that only a meter rule is need for the VSR test (Hui et al, 1999 & 2000). Several authors noted the disadvantaged sit-and-reach performance of participants with lower reach length to leg length or a combination of lower trunk and arm length to leg length (Koen et al, 2003). For that reason, some studies proposed the modified SR test (MSR) to negate the effects of shoulder girdle mobility and proportional differences between arms and legs (Hoeger et al, 1990 & 1992). Some authors suggested that simultaneously stretching both hamstrings in the CSR, VSR and MSR test may result in excessive anterior margins of posterior disc compression due to the anterior portions of the vertebrae being pressed together; therefore the

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Back-saver sit-and-reach test (BS) was proposed (Cailliet-1988; Hui et al, 1999). The BS test evaluates only one leg at a time and requires a sit-and-reach box (Hui et al, 1999 & 2000). However, the investigators often received complaints from participants about the uncomfortable position of the untested leg. For this reason, a modified version of the BS is proposed by the investigators. Modified Back-saver sit-and-reach test (MBS) incorporated the advantages of the VSR and BS.

Often test administrator desires to select a test that allows greatest validity and reliability, with the least equipment and preparation time, and produce the least discomfort to subjects (Hui et al, 2000). The MBS test adopts the notion of single leg stretch, which eliminates the excessive posterior disk compression of the vertebrae (Baltaci et al, 2003) and requires only a measuring rule and a bench, which can be easily prepared in most school settings. It is a practical test that requires minimal preparation time and equipment and without the use of a box. Moreover, the specific posture when performing the test eliminates the abnormal position and discomfort feeling of the unstretched leg, as in the BS test. Furthermore, a teacher might be able to detect some difference in hamstring flexibility from limb to limb that would be hidden in testing with the traditional SR test. This would allow feedback and potential exercises to correct any imbalances that otherwise may lead to potential injury or postural disturbance.

For all the advantages of this protocol, MBS test can not eliminate the effects of shoulder girdle mobility and proportional differences between arms and legs. There have been some studies into the relation between flexibility as measured by the CSR test and anthropometric measures. Some authors have questioned the validity of the CSR test, suggesting that there is an advantage for an individual with a long trunk, long arms, and short legs (Hoeger et al, 1990 & 1992). However a study has not confirmed this claim (Holt et al, 1999). Hoeger et al suggested that the CSR does not control the possible limb-length biases. They indicated that the MSR eliminates concern about disproportionate limb length bias and appeared to be a better test (Hoeger et al, 1990 & 1992).

We hypothesized that the result of MBS test should be normalized by anthropometrical measures. Therefore, this study was designed to examine the role of Sitting height, Arm length, Trunk length, leg length, Arm span, and Sum of trunk and arm lengths on MBS test and to determine the need for normalization of performance data.

2. Methods

2.1. Participants

210 healthy boys, ages 12-18 years, without known impairment of the musculoskeletal system affecting the spine or the lower extremities, volunteered to participate in this study (body mass 57.1±12.4 kg, height 166.4±10.8 cm, age 15.4±1.3 yr, BMI 19.7±2.8 kg/m2; M±SD). All subjects were students in secondary schools. The subjects were carefully informed about the design of the study with special information on possible discomfort and benefit that might result, and subsequently signed an informed consent form prior to the start of the study. The Shomal University Institutional Review Board for Human Investigation approved all experimental procedures.

2.2. Predictive Factors

Standing height was measured by used the stretch stature method. The participant stood with the feet together without shoes, looked straight ahead and inhaled while the measurement was taken. Stature is the maximum distance between the floor and the vertex of the head. Sitting height was the maximum distance from the vertex to the base of the sitting surface when the back and neck were straight and in normal state. Cervical height sitting is occasionally used to estimate trunk length excluding the neck and head (Lohman et al,1988). Body mass was determined with digital scales (Seca 770, Hamburg, Germany) that had a measurement resolution of 0.1 kg. Arm length was determined first by locating the Acromion of the scapula by palpation. The most lateral point on the end of the acromial process of the shoulder blade was marked with a pen and the arm length was recorded as distance from this point to the middle fingertip with the arm extended and held parallel to the floor. Arm span was measured when the arms abducted to 90 degrees, elbows extended, forearms supinated, with the wrist in neutral, and fingers extended. Arm span is the distance between the tips of the middle fingers of each hand when both arms are extended laterally and maximally to the level of the shoulder (Lohman et al, 1988). Leg length was calculated as the difference between standing and Sitting height (Wadsworth et al, 2002). As a new variable, Sum of trunk and arm length was calculated to improve prediction of sit and reach test results. The measurements were made with a plastic tape 2 m long and recorded to the nearest 1 cm and were taken with subjects in light clothes (light vest and mini briefs) without shoes.

2.3. MBS test

In this test, No sit-and-reach box is required, and the participants perform a single-leg sit-and-reach on a 12-inch bench on which a meter rule is placed. The untested leg is placed on floor with knee at approximately 90° (Hui et al, 2000). The subject aligned the sole of the foot (extreme plantar aspect of the calcaneus) of the tested leg with the 50-cm mark on the meter rule. Then, Subjects flexed their hip joints and trunk slowly to reach forward as far as possible, while maintaining the knees, arms and fingers fully extended and keeping the two hands parallel (figure1). Subject held this position momentarily (2sec). The score was the most distant point on the bench contacted by the fingertip (Heyward et al, 2002).

Fig. 1: modified back-saver sit-and-reach test.

2.4. Procedure

Testing took place during the students' physical education classes. In the exercise room participants removed their shoes. Prior to all testing, participants performed an 8-min warm-up and static stretch routine emphasizing the lower body (Jones et al, 1998). Immediately following the stretching, the flexibility tests were performed in a counterbalanced design (Patterson-1996). All tests were assessed on the same day for each student. After a demonstration of test, one practice trial and three test trials (left and right leg) 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 the point of pain (Baltaci et al, 2003). The best score of three trials was used for subsequent analyses. The participants were allowed to rest for 5 min between tests (Minarro et al, 2007).

2.5. Statistical Analysis

Intra-rater Reliability for MBS tests was determined using intraclass correlation coefficients (R) from one-way repeated measures ANOVA procedures. Dependent t tests were performed to compare MBS score of the right and left limbs of participants. Because no significant differences ($p>.05$) were identified, data from the right and left limb trials were averaged. Pearson product–moment correlations were calculated to explore the bivariate relations between MBS test and Arm length, leg length, Trunk length, Sitting height, Arm span and Sum of trunk and arm length. All the variables were found to be significantly correlated, to the MBS test, thus the stepwise multiple regression was used to examine the contribution of anthropometrical measures to the MBS test. Because, only the contribution of Arm span to the percentage of shared variance was significant and Arm span found to be the most highly correlated factor, MBS test were normalized to the participant's Arm span for further analysis. Normalization was performed by dividing each MBS test by a participant's arm span, and then by multiplying by 100. Normalized values can thus be viewed as a percentage of MBS test in relation to a participant's Arm span. The quantitative variables (weight; height; BMI; Arm length; leg length and Trunk length) divided to 3 groups by "Categorize Variables" in SPSS software. Data are categorized based on percentile groups, with each group containing approximately the same number of cases. One way ANOVA test was used for comparison the groups in raw and normalized flexibility data. Age-adjusted associations between MBS score and anthropometric variables were analyzed by using partial correlations. Also age entered as a covariate in Linear multiple regression and analysis of variance. Statistical significance was set at the $P<0.05$ level. These statistical analyses were performed with SPSS software (SPSS 11.5, SPSS).

3. Result

Table 1 provides information on anthropometrical characteristics and flexibility of the participants.

For MBS scores the intraclass reliability (Intra-rater Reliability) for internal consistency (single trial) was very high (ICC=.989), ranging from .97 to .99.

Table 1: Range, Mean and standard deviation of anthropometrical characteristics and flexibility of the participants (cm)

Variables	Sitting height	Arm length	leg length	Trunk length	Arm span	Sum of trunk & arm lengths	Sit-and-reach test	MBS right	MBS left
Range	45-105	37-97	61-112	29-93	123-208	83-181	Raw	29-84	27-83
							Normalized	19.1-48.9	18.6-48.1
M±SD	86.7±6.9	74.9±6.5	89.5±8.7	46.8±7.8	167.9±12.5	121.7±10.9	Raw	59.8±11.3	59.6±10.9
							Normalized	35.6±6.1	35.5±5.9

Table 2. Stepwise multiple regression analysis for anthropometrical measures to predict the MBS scores with controlling age as a covariate

Variable	MBS-Mean			MBS- Right		MBS-Left	
Coefficients	Zero-order Correlation	Partial Correlation (Age)	R2	β	t	β	t
AS	.45*	.28*	.20	.44	7.025*	.44	7.056*
Excluded Variables							
AL	.25*	.14*	.06	.025	.342	.013	.177
LL	.30*	.15*	.09	-.026	-.305	.004	.051
TL	.36*	.19*	.13	.060	.687	.118	1.363
SH	.31*	.12	.10	-.142	-1.405	-.100	-.987
STA	.40*	.23*	.16	.092	.884	.137	1.323
Model Summary				R2=0.192, SEE=10.2, P<0.001		R2=0.193, SEE=9.8, P<0.001	

Note. * P<0.01

A significant correlation ($p<.05$) was found between MBS and anthropometric measures (Table 2). For the significant correlations, r2 values ranged from .06 to .2 between MBS and predictor variables. The strongest correlations were found between Arm span and MBS test (r= .45) and, Sum of trunk and arm lengths and MBS test (r= .40). With controlling age, the partial correlation between MBS (right or left) with predictor variables were less than Zero-order correlation, but still were significant (exept sitting height).

Table 3: Differences in Raw and Normalized MBS test Scores in anthropometric variables

Categorize Variables		Height		Arm length		Leg length		Trunk length		STA	
		F	F	p	F	F	p	F	p	F	p
Raw Scores (cm)	MBS-r	3.621	.028	9.301	3.621	.028	9.301	9.301	.000	20.610	.000
	MBS-l	3.133	.046	11.067	3.133	.046	11.067	11.067	.000	21.514	.000
Normalized (% of Arm span)	MBS-r	.438	.646	.251	.438	.646	.251	.251	.779	4.349	.014
	MBS-l	.322	.725	.458	.322	.725	.458	.458	.633	4.017	.019

Note. df = 2, n = 210

Abbreviation. STA= Sum of trunk and arm lengths

Abbreviations. AL= Arm length; AS= Arm span; LL= leg length; MBS-l= modified back saver sit-and-reach left; MBS-r= modified back saver sit-and-reach right; SH= Sitting height; STA= Sum of trunk and arm lengths; TL= Trunk length; SEE = standard error of estimation

The results of the multiple regression analyses for MBS test, including the multiple R, SEE, β and p values are provided in Table 2. Arm span explained the greatest of shared variance of the MBS test for right and left side (19%). When the age was added to the model, the percentage of shared variance significantly changed (24% in both side; R2 Change=.048). But, when all other variables were added to the equation, the percentage of shared variance increased by only 2% in the right and left sides, indicating that little extra variation was explained after other predictor variables had been included ($p>.05$).

There were significant differences between height, Arm length, Leg length and Trunk length groups in both of the right and left MBS ($p\leq.05$). However, No significant differences between these groups were found in MBS score after normalization ($p>.05$). These results are listed in Table 3. Difference normalized MBS scores in STA group were significant as well as raw score, however, the F value decreased clearly after normalization.

When age entered as a covariate in the model, there were significant differences between height (F=3.883, P=.022 for MBS-right and F=4.415, P=.013 for MBS-left), leg length (F=3.146, P=.045 only MBS-left), trunk length(F=3.386, P=.036 for MBS-right and F=4.42, P=.013 for MBS-left) and Sum of trunk & arm lengths (F=6.259, P=.002 for MBS-right and F=6.486, P=.002 for MBS-left) groups in both of the right and left MBS ($p\leq.05$), but, differences in MBS score between these groups were not significant after normalization ($p>.05$). Difference in raw and normalized MBS scores in Arm length group were not significant when age as a covariate ($p>.05$).

4. Discussion

The results demonstrate that anthropometrical measures were positively related to performance on the MBS test. Thus, we need to modify the effects of limb length bias for MBS as CSR test. Arm span have strongest correlation with MBS and explained the greatest of shared variance of the MBS test. The importance of normalizing flexibility data (by factoring out arm span) was illustrated by the existence of significant difference between subjects with different height, BMI, Arm length, Leg length and Trunk length on raw MBS test scores; however, a lack of these differences was found following normalization of MBS test score to arm span. When using the MBS test as an assessment tool for hamstring and lower back flexibility, considerations for normalization should include arm span. This includes either normalizing MBS test score to arm span or matching paired participants for arm span. However, these results only apply to young boy (age 12-18 years-old). More study is needed to verify this result for other groups (young girls and adults). Because sex (Battié et al,2008), age (Brown & Miller -1998) and heritability (Youdas et al,2008) effect on flexibility that did not controlled in this study. Also sexual maturation may affect flexibility and limb length in boys' age 12-18 years-old. In this study the age adjusted as a covariate in all analyses, but the growth and sexual maturation did not controlled. Although some authors suggest that growth is not a cause of decreased flexibility during the peripubescent period (Feldman et al, 1999) and sexual maturation in pubertal period would not be effective in determining the flexibility (Kanbur et al, 2005), this is an important limitation associated with this study.

From multiple regression analysis we suggested that the arm span contributed to the reported variation in MBS test scores. Also, other anthropometrical measures were highly correlated to arm span. Therefore, after normalizing MBS test scores to the participant's arm span, lack of difference between height, BMI, Arm length, Leg length and Trunk length groups on MBS scores are explainable.

Logically arm span would correlate significantly with MBS test score, as a longer limb would give a participant an advantage in sit-and-reach performance. While the correlations for arm span to MBS test score were significant, it was not especially strong. The highest correlations occurred between arm span and MBS in the two sides, with an r2 value of just .20. This indicates that while arm span is a significant predictor of performance on the MBS test, other factors not assessed for in this study account for the majority of the variance associated with MBS score.

Notion of disproportional limb length bias in the sit-and-reach test was established (Hoeger et al, 1990). Children with long legs and a short trunk, for example, may fail the test even though they have acceptable hamstring muscle length. Sit-and-reach tests involve whole body motion; the score and validity may be influenced by many anthropometric and joint flexibility factors in the shoulders, spine and upper extremities (Hoeger et al, 1990; Grenier et al, 2003). 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, decreased or normal back motion combined with increased hamstring muscle length, or increased back motion combined with decreased hamstring muscle length, anthropometric factors such as long arms or short legs relative to the trunk; and scapular abduction, which increases the reaching distance of the arms (Cornbleet et al, 1996). Nevertheless, shoulders, spine and hamstrings flexibility, hamstring length was not investigated in this study. Another possible predictor of performance was spinal mobility. Subjects with higher spinal mobility could have higher score than others (Grenier et al, 2003).

However, some studies reported that after correcting the SR test scores for proportional differences between arm and leg lengths (Minkler et al, 1994; Hoeger et al, 1990) the correlation coefficient with hamstring flexibility was moderate while the correlation with lower back flexibility was low. Thus, the correction of the CSR performance for proportional differences between arms and legs did not improve the validity evidence for measuring hamstrings and lower back flexibility (Koen et al, 2003).

The MBS incorporated the advantages of the VSR and BS and is the best protocol for hamstring flexibility assessment in school age student. The results of this study suggest that among young boys, non-physically active individuals, arm span of the participants must be considered in normalizing performance data. Future researches directed toward validation of the normalized MBS score in young boys and apply this method in other population (young girls and adult)

5. Conclusion

We recommend that when using the MBS test for experimental purposes in young boys, investigators should either normalize MBS left and right to participant arm span or use control participants who are matched to experimental participants according to arm span

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