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THE RELATIONSHIP BETWEEN STAR EXCURSION BALANCE TEST AND LOWER EXTREMITY STRENGTH, RANGE OF MOTION AND ANTHROPOMETRIC CHARACTERISTICS

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Abstract

Objective: To consider the relationship between hip muscles strength, anthropometric characteristics and range of motion (ROM) with Star Excursion Balance Test (SEBT), a test of dynamic postural control.

Methods: Forty seven persons (23 male, 24 female) volunteered for this study. Maximal Voluntary Contraction (MVC) of hip muscles measured by Manual Muscle Test (MMT). Participants performed 3 trials of the SEBT in each of the 8 directions.

Results: No statistically significant relationship were found between ROM with execution distances ($P > 0.05$). Significant correlations were revealed between height and excursion distance and leg length and excursion distance with leg length having the stronger correlation ($P \le 0.05$). Significant differences were found between excursion distances and hip muscle strength ($P \le 0.05$). Male had significantly greater excursion distances than female participants in posteriomedial, posterior and medial directions ($P \le 0.006$). However, after normalizing excursion distances to leg length, there were no significant differences related to gender.

Conclusion: In conclusion, when using the SEBT for assessment balance, participants' execution distances should be normalized to leg length and lower extremity strength to diminish individual and gender differences.

Key words*: dynamic balance, SEBT, strength, ROM, anthropometry*

Introduction

Balance is an important component of daily activity and athletic performance [1]. Balance is the single most important component of athletic ability and is involved in nearly all forms of movements [2]. The measurement of postural control is an important tool in the assessment of pediatric, geriatric and athletic populations for establishing levels of neuromuscular function in the context of injury prevention and rehabilitation. Postural control is often described as being either static (attempting to maintain a position with minimal movement) or dynamic (maintaining a stable base of support while completing a prescribed movement) [3]. Static postural control is commonly quantified through instrumented measurements of ground reaction forces or less sophisticated non-instrumented means [4].

Dynamic postural control often involves completion of a functional task without compromising one's base of support. The advantage of assessing dynamic postural control is that additional demands of proprioception, range of motion (ROM), and strength are required along with the ability to remain upright and steady. Numerous tests have been developed to assess dynamic postural control in the pediatric [5] and geriatric [6] populations, but very few tests that truly stress the dynamic balance capabilities of the healthy, athletic population. The Star Excursion Balance Test (SEBT) is one such test that provides a significant challenge to an athlete's postural control system [7].

During this test, a participant maintains a base of support with one leg while maximally reaching in different directions with the opposite leg, without compromising the base of support of the stance leg.

The SEBT has shown sensitivity in screening for functional deficits related to musculoskeletal injuries [8,9]. In addition, Earl [10] and Hertel et al. [11] demonstrated the usefulness of the SEBT for the recruitment of lower extremity musculature contraction and discussed its application in rehabilitating various lower extremity musculoskeletal injuries [7].

Researchers have provided evidence that SEBT is sensitive for screening musculoskeletal impairments, such as chronic ankle instability [9], quadriceps strength deficits [8], and patellofemoral pain syndrome [10]. Olmsted et al. [9] reported decreased reaching distances during performance of SEBT in patients with chronic ankle instability compared to matched-healthy control participants [9].

Miller [8] correlated quadriceps strength deficits with performance of the SEBT among subjects who had undergone anterior cruciate ligament reconstruction. Earl [10] found that when assessing function among patients with patellofemoral pain (PFP), the patients with PFP had significantly reduced performance on the SEBT compared to matched controls.

Various factors of static postural control measures, such as muscle strength, architectural foot type, and mental status, have been studied [11,12]. However, predictive factors for performance of the SEBT have not been examined. This study was designed to examine the role of gender, height, leg length, and lower extremity strength and ROM measurements on dynamic postural control as assessed through the SEBT and to determine the need for normalization of performance data.

Methods

Subjects

Forty seven (23 men, 24 women) recreationally active participants volunteered for this study. Descriptive data of the participants is presented in Table 2. Subjects signed an informed consent form and answered a demographic/injury history questionnaire, which was used to obtain background information from each subject. All participants reported that they were free of vestibular disorders, cerebral concussions, and lower extremity injuries during the previous 6 months.

Measurements of lower extremity strength

Maximum voluntary contraction (MVC) of hip muscles was measured by manual muscle test (MMT). To test hip flexors strength, subject seated on a bench that does not allow the feet to touch the ground with their hips and knees at a 90° angle. The subject flexes the hip approximately 8 inches off the bench and a downward force is applied by the examiner. Position the curved plate was just proximal to the top of the patella. Subject maintains a torso position that is perpendicular to the table, while gripping the sides of the table for stabilization [13].

To test hip extensors, participants were instructed to lie prone on the examination table such that the MMT was above the middle third of their posterior thigh. The leg to be tested is raised about 3 to 4 inches off the table. Before testing, participants were instructed to flex the knee of the leg being tested (60°–90°) and to raise it vertically into the forceplate during each trial [14].

To test hip adductors, the position is similar to the test for abduction, except that the lower leg is being tested and the upper leg is bent and crossed in front the body so that the sole of the foot rests on the table. The lower leg is adducted about 6 inches off the table and a downward force is applied. Position the curved plate just proximal to the medial malleolus, do not impact the leg into the table [14].

To test the hip abductors, with the subject sidelying, the leg under examination is superior to the supporting leg. The limb under examination is slightly extended beyond and the supporting leg is flexed for stability. The subject grasps the table with the ipsilateral hand to provide stabilization and to prevent rolling. The leg to be tested is raised about 12 inches off the table. The MMT is placed on lateral surface of knee and resistance by examiner is straight and downward. The subject abducts against the applied resistance without flexing or rotating the hip in either direction [15].

Participants performed 3 consecutive trials (ie, contractions) for each of the muscle groups being tested. Before testing, participants were instructed to give a maximal isometric effort during each trial. Trials lasted 2 to 4 seconds. The 3 trials for each muscle in each session were separated by 5 seconds of rest. Once pressure was applied to the MMT, tester resisted with as much force as was necessary to maintain the MMT in a static position. For each of the four hip muscles tested, a maximal value was computed from the three test repetitions obtained.

Measurements of Predictive Factors

Height was measured with a standard height chart. Leg length was measured on limb with participants lying supine. A tape measure was used to quantify the distance from the anterior superior iliac spine to the center of the ipsilateral medial malleolus. Hip internal and external rotation was measured with a standard goniometer with the participants lying prone. Dorsiflexion at the ankle was also measured with a standard goniometer with the participants standing with one foot in front of the other while leaning forward until the heel of the posterior foot began to lift off the ground [16].

Star Excursion Balance Test

The SEBT was performed with the participants standing in the middle of a grid formed by eight lines extending out at 45° from each other. The participant was asked to reach as far as possible along each of the eight lines, make a light touch on the line, and return the reaching leg back to the center, while maintaining a single-leg stance with the other leg in the center of the grid. Participants were instructed to make a light touch on the ground with the most distal part of the reaching leg and return to a double-leg stance with out allowing the contact to affect overall balance. The terminology of excursion directions is based on the direction of reach in relation to the stance leg (see Fig. 1). Participants were allowed to practice reaching in each of the eight directions six times to minimize the learning effect. Following a 5-min rest period, participants performed three trials in each of the eight directions. The order of

Fig. 1. *Performance of the Star Excursion Balance Test with a left stance leg reaching into the posteromedial direction*

testing was randomly. The investigator recorded each reach distance with a mark on the tape as the distance from the center of the grid to point of maximum excursion by the reach leg. If the investigator felt the participant used the reaching leg for a substantial amount of support at any time, removed his or her foot from the center of the grid, or was unable to maintain balance on the support leg throughout the trial, the trial would be discarded and repeated [17].

Statistical analysis

A series of eight independent t tests was used to examine the differences in normalized excursion distances in the eight directions as a function of gender. Pearson product–moment correlations were calculated to explore the bivariate relations between excursion distance and hip muscles strength, height, leg length, hip internal ROM, hip external rotation ROM, and ankle dorsiflexion ROM.

Leg length and height were both found to be significantly correlated, to reach distance in the majority of the directions (see Table 1), thus the Pearson product–moment correlation between height and leg length was calculated ($r = 0.85$). Because leg length was found to be the most highly correlated factor, and leg length and height were highly correlated, excursion distances were normalized to the participant's leg length for further analysis. Normalization was performed by dividing each excursion distance by a participant's leg length, and then by multiplying by 100. Normalized values can thus be viewed as a percentage of excursions distance in relation to a participant's leg length.

Table 1. *Relationship between height and excursion and leg length and excursion (r values)*

Reaching Direction	Height	Leg Length
Anterior	0.46**	0.52**
Antromedial	0.45**	0.47**
Medial	0.41*	0.36*
Posrromedial	0.38*	0.41*
Posterior	0.35*	0.36*
Postrolateral	0.23	0.24
Lateral	0.13	0.17
Antrolatrral	0.36*	0.45**

** $P < 0.05$ * $P < 0.01$

Results

Descriptive data of the participants is presented in Table 2.

Table 2. *Descriptive data of the participants*

Gender	Age (yr)	Weight (kg)	Height (cm)	Leg length (cm)
Male ($n = 23$)	21.35	77.44	176.42	90.14
Female ($n = 24$)	19.57	67.25	165.14	84.25

No significant correlations were found between hip internal rotation, hip external rotation or ankle dorsiflexion and excursion distances ($P > 0.05$).

Table 3. *Differences in normalized excursion distances for men and women*

Reaching direction	Raw Scores (cm)			Normalized (% of leg length)		
	male	female	P	male	female	P
Anterior	70/4±6/9	65/5±10	0.42	77.2±6.8	74.1±6.2	0.76
Antromedial	72.2±9	68.6±7.7	0.056	79.6±11.7	77.4±6.6	0.061
Medial	83.5±10.1	74.1±9.2	0.001*	90.3±10.1	87.3±9.6	0.54
Posrromedial	83.6±7	75.3±8.6	0.001*	91.1±7.4	89.7±7.1	0.082
Posterior	81.6±9.3	72.2±11.7	0.005*	89.2±6.2	86.2±8	0.31
Postrolateral	79.5±11.4	76.9±6.5	0.021	88.4±7.6	86.8±5.4	0.241
Lateral	75.3±9.7	72.6±6.3	0.027	84.7±5.7	72.1±7.1	0.547
Antrolatrral	67.9±8.5	65.5±5.4	0.43	72.5±9.3	73.1±7.1	0.423

Note. Means of three trials and standard deviation values in each reaching direction. Scores adhere to a Bonferroni correction level of significance of $P < 0.006$ (0.05 divided by number of reaching directions, 8)
* $P < 0.006$

Table 4. *Relationship between lower extremity strength and excursion*

Reaching direction	hip flexion strength	hip extension strength	hip abduction strength	hip adduction strength
Anterior	0.51**	0.39*	0.08	0.09
Antromedial	0.47**	0.07	0.42**	0.07
Medial	0.37*	0.12	0.35*	0.37*
Posrromedial	0.11	0.36*	0.41**	0.15
Posterior	0.35*	0.48**	0.13	0.08
Postrolateral	0.09	0.42**	0.46**	0.34*
Lateral	0.14	0.19	0.39*	0.37*
Antrolatrral	0.42**	0.14	0.10	0.31*

** $P < 0.05$. * $P < 0.01$

Men were found to have significantly greater raw excursion distances than women in three of the eight reaching directions (posterior, posteriomedial, medial) ($P < 0.006$). However, following normalization no significant differences between genders were identified ($P > 0.06$). These results are listed in Table 3.

Relationship between lower extremity strength and excursion is presented in Table 4.

Discussion

Our results demonstrate that hip muscles strength was positively related to performance on the SEBT. The SEBT requires neuromuscular control though proper joint positioning as well as strength in surrounding musculature to create and maintain the necessary positions throughout the test.

The current investigation suggested that there was co-contraction of the quadriceps and hamstring during all direction of excursion. The quadriceps was most active during the 3 anteriorly directed excursions. To perform the anterior directions, subject leaned backward, extending the trunk, to maintain their balance. Gravity action on the upper body creates a large knee-flexion moment, which must be controlled by an extension moment produced by the quadriceps. High vastus lateralis activity during the medial and posteromedial excursions might be the result of muscular stabilization against the varus force created at the knee with these directions [18].

During the SEBTs the biceps femoris was most active during the posterior, posterolateral, and lateral excursions. High activity during the two posterior excursions can be explained by gravity acting on the trunk, causing a hip-flexion moment. As the leg is extended backward the trunk flexes to maintain balance. The hamstrings must eccentrically contract to resist this hip-flexion moment. This finding is supported by previous research that indicated increased hamstring activity as the trunk angle increased [19]. External rotation at the hip during the lateral excursion further increases biceps femoris activity as it function to externally rotate the hip.

Core stabilization training improves neuromuscular system efficiency that leads to optimal arthrokinematics in the lumbopelvic-hip complex during functional kinetic chain movements, optimal acceleration, deceleration, optimal muscular balance and provides proximal stability for efficient lower extremity movements [20].

Hip muscular strength provides proximal stability for efficient lower extremity movements that lead to optimal function and lower extremity muscles strength, that can eliminate produced torque during reaching in SEBT. Consequently subjects can obtain more reach distance in SEBT.

Our results showed that leg length were positively related to performance on the SEBT. The SEBT involves maximizing lower extremity reach distance with one limb while maintaining balance on the contralateral limb. Logically leg length would correlate significantly with excursion distance, as a longer limb would give a participant an advantage in reaching that limb further. In addition, because height and leg length strongly correlate with each other, it is inherent that height and excursion distance would also correlate significantly [21]. The existence of significant differences in excursion distances between genders may result from raw excursions distance scores; however, a lack of gender differences may found following normalization of excursion distances to leg length.

No relation was found between ROM measurements at the hip and ankle and performance on the SEBT. We allowed participants ample practice of the SEBT, but we did not dictate their strategy for achieving maximum reaching distance beyond what was described. Thus, an individual could incorporate a variety of movement patterns for positioning of the trunk as well as the joints of the upper and lower extremities. Variations in ROM at the hip and ankle among individuals did not affect overall dynamic balance performance with the SEBT. Because we did not require a specific pattern of movement to achieve maximum performance, an individual conceivably could overcome a deficit in range of motion at one joint by using more ROM at another joint to achieve the specified goal [21].

This study was designed to examine the role of factors on SEBT. Other factors that may be associated with variations in performance include the following: neuromuscular control, fatigue and strength and ROM at additional muscles and joints.

The SEBT is a promising test of postural control that may be useful in assessing functional deficits in those with lower-extremity orthopedic injuries. The results of this study suggest that among young, physically active individuals, leg length and lower extremity of the participants must be considered in normalizing performance data. We recommend that when using the SEBT for experimental purposes, investigators should either normalize excursion distances to participant leg length and lower extremity muscle strength or use control participants who are matched to experimental participants according to leg length and strength.

Declaration of interest

The authors report no conflicts of interest.

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