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INFLUENCE OF ANKLE PASSIVE RANGE OF MOTION ON THE PERFORMANCE OF THE STAR EXCURSION BALANCE TEST

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The purpose of this study was to measure the association between ankle passive range of motion (PROM) and the horizontal distance reached during the Star Excursion Balance Test (SEBT). Nineteen participants without any musculoskeletal and neurological injury performed the SEBT on eight directions proposed in the original protocol. The ankle PROM was measured with a manual goniometric device prior to the performance of the test. To determine the association between the distance reached during SEBT and the ankle PROM, we used the Pearson Correlation Coefficient Test ("r"). All directions of SEBT showed low correlation with the ankle PROM without significant differences for any variable. We concluded that the ankle PROM is not a confounding variable that should be monitored for use the SEBT for healthy individuals.

KEY WORDS: ankle passive range of motion, Star Excursion Balance Test, dynamic postural control.

INTRODUCTION: Several tests are used to measure the dynamic postural control. The Star Excursion Balance Test (SEBT) is a test characterized by the attempt to maintain stability with a single stance while the opposite limb tries to reach the maximum possible horizontal distance on eight different directions, three anterior, two lateral and three posterior (Kinzey & Armstrong, 1998; Hertel, Miller & Deny, 2000; Gribble & Hertel, 2003, Gribble et al., 2004).

Results achieved in studies that used SEBT showed that this test causes a greater perturbation on the stability of individuals than other tests used with the same purpose (Herrington et al., 2008, Gribble et al., 2009, Hertel et al., 2000). Moreover, their clinimetric properties had excellent results, demonstrating a good intra- and inter-examiner reliability, with an Intraclass Correlation Coefficient varying between 0.67 and 0.96, depending on the direction performed (Kinzey & Armstrong, 1998; Hertel et al., 2000).

Its validity as a predictor of injuries and as an instrument of evaluation of the functional status of the lower limbs has been demonstrated by studies that examined subjects with and without chronic ankle instability (CAI), anterior cruciate ligament (ACL) injuries and patellofemoral pain syndrome. There are evidences that subjects with CAI and ACL injuries demonstrated lower results, with regard to maximum horizontal distance, and less hip and knee flexion, in comparison with healthy subjects (Gribble et al., 2004; Gribble et al., 2009; Herrington et al., 2008, Aminaka et al., 2008).

Despite the validity of the SEBT, it is believed that the maximum horizontal distance reached by the lower limb can suffer influence from some anthropometric and biomechanics variables, such as leg length and the angular displacement of joints. This fact increases the need for a standardization of parameters to determine criteria to reduce the level of influence to this kind of confounding variables in the final result (Gribble & Hertel, 2003; Robinson & Gribble, 2008).

Robinson & Gribble (2008) identified that the active hip flexion of the lower limb of stance is a good predictor of performance in the medial, posterior, posterior-lateral and posterior-medial directions of the SEBT, as well as the active knee flexion is a predictor in the anterior-lateral and anterior-medial directions. Together, these variables are also predictive in the lateral and anterior directions. However, this study examined the active hip and knee range to motion (ROM), without controlling the PROM allowed for each joint. Furthermore, the ankle is of the

more distal joints of the biokinematic chain of the lower limbs and, consequently, any change in their displacement tends to induce changes in the proximal elements of the chain. However, it was not found studies that have measured the ankle PROM during execution of SEBT in order to estimate their level of influence on the performance of SEBT.
In this perspective, the purpose of the present study was to measure the relation between the ankle PROM and the maximum horizontal distance reached in the SEBT. The experimental hypothesis was that the ankle flexion PROM would be associated with the performance during the SEBT.

METHODS: Ten men and eight women (22.1 ± 2.1 years, 1.71 ± 0.99 m, 72.9 ± 13.1 kg) were volunteers for this study. No participant had any type of musculoskeletal injury in the lower limbs or any neurological deficit that adversely affects dynamic postural control. All participants signed an informed consent and this study was approved by the Ethics Committee of the State University of Rio de Janeiro.
The anthropometric variables examined in this study were: height, body mass (BM), ankle PROM and length of the dominant lower limb. All measurements were performed by the same examiner and the protocol proposed by the International Society for the Advancement of Kineanthopometry was followed (ISAK, 2006). The BM was measured by an analog weighting scale with a resolution of ± 0.1 kg (Filizola ®, São Paulo, Brazil) and the height was measured with a stadiometer attached to the same equipment. The length of the lower limb was measured with subjects on the standing position with the distance between each subject's feet normalized to individual hip-width stance. The evaluator localized the greater throcanter and measured the height of the lower limb from that point to the floor. The ankle PROM was measured with a manual goniometer (CARCI ®, Brazil), with subjects positioned on supine position, with the hip and knee of the dominant leg flexed at 90° and the heel of the same limb, supported on a flat surface.
The SEBT was executed with the participant positioned at the intersection of the eight lines marked on the floor separated by an angle of 45° each, according to Robinson & Gribble (2008). The participant was instructed to reach the maximum possible horizontal distance in each of the lines with their arms crossed across the shoulders, standing on a single stance on the dominant leg. The reach limb could not touch the ground, until reach the maximum distance. Thereafter it should be returned to the starting position of double support.
Before starting the test, the participants executed four practice trials for each direction (Robinson & Gribble, 2008), to reduce the influence of learning effect on the results of subsequent attempts. After the familiarization with the testing procedure and resting for five minutes, the participants executed three trials of tests for each of the eight directions. The individuals rested two minutes between each trial. The order of directions was randomized. The dominant leg was determined as the favorite limb which the subject kicked a ball as far as possible. The distance reached in each trial was marked by one trained evaluator when the subject slightly touched the floor. The trial was not valid if the subject moved the stance leg, took off the heel from the floor or could not keep in balance.
Statistical Analysis: The Pearson Correlation Coefficient test ("r") was used to measure the relation between the ankle PROM and the performance during SEBT. The coefficient of determination ("r^2") was used to explain the variability of the ankle PROM due to the performance during SEBT.

RESULTS: The correlation between the ankle PROM and the distances reached in the SEBT was low in all directions, without significant results ($p > 0.05$). The average values of the distances reached in each direction, the coefficients of correlation ("r"), the coefficients of determination ("r^2") and the p value are described in Table 1.

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Table 1
Description of the normalized distance (mean ± standard deviation), Pearson Correlation Coefficient (“r”), coefficient of determination (“r^2”) and p-value for each direction of the SEBT

Direction	Normalized Distance	r	r^2	p value
A	0.87 (± 0.07)	0.34	0.12	0.1620
AL	0.64 (± 0.1)	0.25	0.06	0.3184
AM	0.94 (± 0.07)	0.17	0.03	0.5035
L	0.87 (± 0.1)	-0.27	0.07	0.2696
P	0.98 (± 0.07)	0.08	0.006	0.7629
PL	0.95 (± 0.09)	-0.24	0.06	0.3272
PM	0.96 (± 0.08)	-0.04	0.002	0.8762
M	0.98 (± 0.07)	0.08	0.007	0.7477

A: Anterior; AL: Anterior-Lateral; AM: Anterior-Medial; L: Lateral;
P: Posterior; PL: Posterior-Lateral; PM: Posterior-Medial; M: Medial.

DISCUSSION: The purpose of this study was to measure the relation between the ankle PROM and the horizontal distance reached during SEBT. Based on the results it was not possible to accept the experimental hypothesis that the ankle PROM was associated with the performance of individuals performing the SEBT, considering the low values of correlation found. This low association could be explained at least in part by the high influence of hip and knee flexion in the SEBT performance (Robinson & Gribble, 2008), variables not controlled in this study.

This important finding suggests that the ankle PROM is not a confounding variable that needs to be normalized among healthy participants in future studies. This may have occurred due to the compensation of others joints in the biokinematic chain.

The literature reports that hip and knee have an average of 135° flexion angle (Hamill & Knutzen, 2008). So, according to the results of the study of Robinson & Gribble (2008), there is no anatomical limitation to the displacement of these joints, during the execution of this test, since these joints have a maximum angle no greater than 70° during the execution of SEBT (Robinson & Gribble, 2008). On the other hand, the ankle has a maximum anatomic flexion angle of only 25° (Hamill & Knutzen, 2008). In the execution of the SEBT this small angular displacement allowed can cause an anatomical limitation because the participant can reach maximum flexion of this joint. In this condition it is expected that a strategy to increase the maximum distance of the reach limb could be the use of compensatory actions of hip and knee joints.

These strategies require that the individual has a good intersegmental coordination. The elements of the biokinematic chain should adjust their behavior in such a way that the total, functionally important output of the whole system is unchanged. To ensure this, if one element changes its behavior, other elements should change their movement to compensate it. This mode of functioning is called the principle of maximal interaction (Latash, 2008). This principle implies, in particular, that if a perturbation is applied to one of the elements of a structural unit, it is expected to lead to changes in the contributions, not only of the perturbed one but also of other elements. The purpose of these changes is to correct errors in the common functional output of the structural units that were introduced by the changed contribution of the perturbed element (Latash, 2008). Therefore, it is important, in future works, to study the coordination during the execution of the SEBT.

Despite its importance, the intersegmental coordination is not the only fact that could affect the results of the SEBT. Although it is possible to increase the hip and knee flexion to compensate the inability of the ankle, the more the hip, the knee and the trunk flex, the more the vertical projection of center of gravity (CoG) moves beyond the limits of the base of support. When the CoG is projected off the base of support, occurs the condition of loss of balance (Hamill & Knutzen, 2008). Therefore, it is possible that the capacity of increase the

displacement of the lower limb joint keeping in balance should be the greater challenge of this exercise. If this hypothesis is confirmed in future studies, this test could be used not only to assess dynamic postural control, but also the intersegmental coordination.
One of the limitations of the present study was the procedure for measuring the distance reached in each trial, which was done manually.

CONCLUSION: In the present study the correlation between ankle PROM and the distance reached during the execution of the SEBT was very low and showed no significant difference in either direction. These results suggest that ankle PROM does not seem be a confounding variable to be controlled in studies with a sample of healthy individuals. We suggest future researches with the aim of (i) verifying the influence of ankle active ROM and intersegmental coordination in the SEBT; and (ii) investigating whether individuals with different sports injuries such as ankle sprains and ACL injuries, have limitations in the joint movement that influence the results the SEBT.

REFERENCES:

Aminaka, N. & Gribble, P.A. (2008) Patellar Taping, Patellofemoral Pain Syndrome, Lower Extremity Kinematics, and Dynamic Postural Control. *Journal of Athletic Training*, 43(Suppl. 1), 21-22

Gribble, P.A & Hertel, J. (2003). Considerations for normalizing measures of the Star Excursion Balance Test. *Measurement in Physical Education and Exercise* Science, 7, 89-100.

Gribble, P.A., Hertel, J., Denegar, C.R & Buckley, W.E. (2004). The effects of fatigue and chronic ankle instability on dynamic postural control. *Journal of Athletic Training*, 39, 321-9.

Gribble, P.A., Robinson, R.H., Hertel, J. & Denegar, C.R. (2009). The Effects of Gender and Fatigue on Dynamic Postural Control. *Journal of Sport Rehabilitation*, 18, 240-257.

Hamill, J., Knutzen, K.M. (2009). *Biomechanical Basis of Human Movement*. 3 ed. Philadelphia: Lippicott Williams and Wilkins

Herrington, L., Hatcher, J., Hatcher, A. & McNicholas, M. (2009). A comparison of Star Excursion Balance Test reach distances between ACL deficient patients and asymptomatic controls. *The Knee*, 16, 149-52

Hertel, J., Miller, S. & Denegar, C.R. (2000). Intratester and intertester reliability during the Star Excursion Balance Test. *Journal of Sport Rehabilitation*, 9, 104-16

Kinzey, S. & Armstrong, C. (1998). The reliability of the star-excursion test in assessing dynamic balance. *Journal of Orthopaedic & Sports Physical Therapy*, 27, 356-60

Latash, M.L. (2008). *Synergy*. New York: Oxford University Press, Inc.

Robinson, R.H. & Gribble, P (2008a). Kinematic predictors of performance on the Star Excursion Balance Test. *Journal of Sport Rehabilitation*, 17, 347-357

Robinson, R.H. & Gribble, P.A. (2008b). Support for a reduction in the number of trials needed for the Star Excursion Balance Test. *Archives of Physical Medicine Rehabilitation*, 89, 364-70.

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