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Impact of Lower Extremity Muscle Fatigue on Performance of the Star Excursion Balance Test in Healthy Volunteers

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Abstract. Examining the effects of lower extremity muscle fatigue in regards to performance on the Star Excursion Balance Test (SEBT) is the purpose of this study. The SEBT requires participants to reach in eight directions. An isokinetic dynamometer fatigued three muscle groups (knee extensors, hip abductors, and hip extensors) in 32 healthy participants aged 18-30. Each group was fatigued in three separate sessions one week apart after baseline testing. Muscle fatigue was reached when isokinetic force output was decreased by 50%. After fatigued SEBT reach distance was measured. A repeated measure ANOVA determined effects of fatigue on SEBT performance. The hypothesis was that SEBT performance would be altered following fatigued conditions.

1. Introduction

Dynamic balance is needed to maintain center of mass within the base of support with movements that require muscle control in response to some type of disturbance [1]. Numerous studies have used the SEBT to measure dynamic control during balance activities, which consists of integrated closed kinetic chain movements throughout the lower extremity (LE) [2]. It is unknown if muscle fatigue results in altered SEBT scores.

Previous studies show fatigue to be a major impairment that limits balance activities [1,3]. Quadriceps fatigue induced with isokinetic dynamometry results in adverse effects on a single leg stance balance tests [3]. In standing activities, the hip is the most proximal component of LE musculature involved, so it is important to note that fatigue may increase the likelihood of injuries above and below this joint [4]. Muscle fatigue of at least 50% may increase the risk of injury because of decreased balancing ability [1]. Although previous research has found the SEBT to be a good assessment of dynamic control, no studies have shown the relationship of fatigue in LE muscles and performance on the SEBT. Therefore, the purpose of our study was to determine the effects of knee and hip muscle fatigue on performance of the SEBT.

We hypothesize that LE muscle fatigue will negatively affect performance scores of SEBT.

2. Experiment, Results, Discussion, and Significance

A single-group, pretest-posttest repeated measures design was used. Lower-extremity muscle fatigue was the independent variable, with three levels: knee extensors, hip abductors, and hip extensors. The dependent variables were mean SEBT reach distance of three attempts in each of the 8 SEBT directions (anterior [A], anterior-medial [AM], medial [M], posterior-medial [PM], posterior [P], posterior-lateral [PL], lateral [L], and anterior-lateral [AL]).

Thirty-two healthy volunteers, nine male and 23 female, between the ages of 18 and 30 (avg. age 23.84 years) participated in this study.

After screening participants and receiving informed consent, leg dominance was determined using three tests [5]. The dominant leg was the stance leg for the entire study. Following a three minute warm-up and stretching of both lower extremities, participants performed six practice trials [6]. The participant stood on the ball of the dominant foot at the center of a grid with eight intersecting lines running in eight directions at 45° relative to one another. The participant reached the maximal distance possible with the non-dominant, "reach" leg. The participant then returned to center and repeated until all directions were complete. The participant was advised that if balance was lost or stance foot lifted, the trial would be discarded. Participants were not provided feedback during testing.

Each muscle group was tested in a separate session with a coin flip determining a random test direction (clockwise or counterclockwise). Sessions occurred one week apart, and participants were given the same warm-up/stretching protocol consistently. At the second session, baseline measurements were taken (the average of three SEBT trials). After 10

minutes of rest, the fatigue protocol was initiated for the knee extensors. On successive weeks the fatigue protocol was applied to hip abductors and extensors. After fatigue, participants immediately performed three SEBT trials before cooling down.

The means of the baseline and the three trials in each of the eight directions was calculated. Each direction was analyzed individually with the baseline average in the same direction. This was performed for each muscle group resulting in eight separate paired samples t tests calculated through the SPSS statistical software. The level of significance was previously set at 0.05 for all analyses.

Table 1: Baseline vs. Quad, Gluteus Medius and Gluteus Maximus

Direction		Mean	SD	P
A	Baseline	83.45	6.52	
	Knee Ext	81.96	7.73	0.127
	Hip Abd	78.73	5.90	0.000*
	Hip Ext	77.75	6.39	0.000*
AL	Baseline	78.93	7.64	
	Knee Ext	76.73	7.63	0.029*
	Hip Abd	74.56	7.46	0.000*
	Hip Ext	74.89	7.57	0.000*
L	Baseline	79.94	11.14	
	Knee Ext	79.26	10.96	0.648
	Hip Abd	80.46	8.74	0.671
	Hip Ext	80.05	9.34	0.936
PL	Baseline	97.27	10.16	
	Knee Ext	96.16	10.29	0.207
	Hip Abd	96.81	8.06	0.639
	Hip Ext	94.65	10.73	0.151
P	Baseline	110.14	9.84	
	Knee Ext	107.52	9.43	0.003*
	Hip Abd	106.35	8.34	0.000*
	Hip Ext	105.58	9.77	0.000*
PM	Baseline	105.72	9.08	
	Knee Ext	102.75	9.47	0.012*
	Hip Abd	102.63	8.47	0.000*
	Hip Ext	101.36	9.54	0.000*
M	Baseline	97.35	7.56	
	Knee Ext	95.43	8.31	0.003*
	Hip Abd	92.85	7.26	0.000*
	Hip Ext	91.32	8.79	0.000*
AM	Baseline	88.18	7.63	
	Knee Ext	87.06	7.76	0.265
	Hip Abd	85.29	6.63	0.009*
	Hip Ext	83.85	6.85	0.000*

Ext=extensor; Abd=Abductors

The paired samples t test comparing baseline to the fatigued knee extensors revealed significant differences in the directions of AL, P, PM, and M ($P < 0.005$). Comparing baseline to the hip abductors and baseline to hip extensors revealed significant differences in all reaching directions except L and

PL ($P < 0.005$). Mean reach distances were found to be less than the baseline value in all of the eight directions except Lateral for the hip abductors and hip extensors, but this was not found significant. In Table 1, the mean and standard deviation (SD) of each of the fatigued muscle groups are compared to the baseline means for each of the SEBT reaching directions. An asterisk (*) represents a significant difference in reaching distance when compared to baseline.

Knowledge of the relationship between proximal LE muscle fatigue and balance may be just as clinically important as that of muscle fatigue or distal instability. As expected, significant decreases in SEBT scores were found in all muscle groups tested, but unexpectedly, not in all directions. Possible reasons certain directions were unaffected could be (1) muscle performance is increased due to biomechanical factors, or (2) other hip musculature compensates for the fatigued muscle group. The clinical significance and generalizations regarding our results must be confined to young (college-aged) healthy individuals. Our results should be considered when implementing the SEBT clinically. Scores may be negatively affected if the SEBT is done following therapeutic exercise.

3. Conclusions

Fatigue of the knee extensors, hip abductors and extensors by at least 50% significantly affected performance negatively on the SEBT as a whole. In a young, healthy population, exercises that may lead to fatigue of these muscle groups should be done after the SEBT (as a measure of balance) is performed, to minimize the effect on test scores.

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