Loading Posture Control in Anterior and Posterior Positions Using SEBT

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Abstract. Objective: The Star Excursion Balance Test (SEBT) is a valid method to measure dynamic balance. Load carriage in anterior and posterior positions would have different balance control ability. Methods: Twenty healthy young males were volunteered to this experiment and performed SEBT with load carriage in anterior and posterior positions in 0%, 5%, 10%, 15% and 20% body weight loads. Vicon system and MATLAB software were used to calculate the result of SEBT. ICC and One-way Analysis of Variance (ANOVA) with repeated measures analysed the variation tendency and one-way ANOVA analysed the differences between each condition. Results: The normalized excursion distance (%) has decreasing trends with the increase of loads no matter anterior or posterior positions. Load carriage would cause balance disturbances. However, posterior position shows significant decreasing trends while anterior position shows modest decreasing trends. In addition, anterior positions show larger results of SEBT than posterior positions among almost all the conditions. It indicated that anterior positions have higher balance control ability than posterior positions. Conclusion: From the Cyto Scape-web which is used to show the differences between each weight of loads, 0% and 5% loads indicate significant differences compare with other loads in posterior position. On the other hand, 0% and 20% loads show significant differences in anterior position. It observed that above 5% loads were affect balance control ability for load carriage in posterior position and below 20% loads was the avoidable weight to anterior position. This study provides new measure to test the dynamic balance during load carriage. Load carriage would cause injury due to overbalance, anterior position has higher risk than posterior position.

Introduction

The Star Excursion Balance Test (SEBT) is a normal and valid outcome measure to check dynamic balance. Gray developed this test as a rehabilitative tool and then it becomes a clinical use for athletic and pathologic populations [1]. It covers a range of fields including screening [2, 3], injury identification [4, 5], training and rehabilitation [6, 7, 8]. The Star Excursion Balance Test needs to perform how far they can reach without overbalance. This test requires individual to reach along a significant line with one lower limb while standing on the other lower limb [9]. The reaching distance is taken to be related with dynamic balance [10]. Farther distance reached suggests better dynamic postural-control. Due to the individual difference, the Star Excursion Balance Test do not have unified standard. Compared between uninjured and injured lower limbs or before and after treatment or intervention are the normal methods to analysis results [11] . The Star Excursion Balance Test also demands individual performed in the 8 reach directions. As it developed, three reach directions were recommended (anterior, posteromedial and posterolateral reaches were preserved) [12, 13]. Gribble et al. [14]found these three directions has excellent reliability.

Load carriage is a normal weighted carry method used in recreational, military pursuits, and other fields [15, 16]. Tzu-wei et al. [17] supported that load carriage could increase the work and metabolic cost. It is established that could raise the risk of injuries, joint problems and muscle strain whether posterior or anterior positions [18, 19]. Load carriage in anterior positions is specified to distinguish it from posterior positions [20]. Chow et al. [21] indicated that a load carriage carried anteriorly might be responsible for postural changes. Load carriage is considered that could induce postural imbalance

whether static and dynamic conditions due to shifting the posterior and superior the combined centre of mass of load carriage system (loads plus individual) [22, 23]. However, current studies have researched the load carriage on static balance or gait analysis. Very few studies have investigated the load carriage with other balance measurement. Moreover, load carriage in anterior position has been relatively unexplored.

Consequently, this study aimed to investigate the differences of balance control ability between anterior and posterior positions during load carriage. The SEBT was used to test the dynamic balance. It was hypothesised that increasing loads would have a variation tendency of the Star Excursion Balance Test results and that different load carriage positions (anterior and posterior) could change the performance of the Star Excursion Balance Test.

Methods

Twenty young healthy males participated in this experiment. All of them were Ningbo University students. Table 1 listed the personal information. They were free from injury and pain. In addition, there were no large surgery in the past six months. In order to check the health condition and balance order, all the participants completed patient reported outcome measures including Tegner Activity Level Scale [24], Lower Extremity Functional Scale (LEFS) [25], Visual Analog Scale (VAS). Results are provided in Table 1 and all the participants were qualified.

Table 1 Participant demographics

	Total
Participants	20
Age (years)	25.0±2.1
Height (cm)	176.0±2.3
Weight (kg)	64.0±5.5
Right leg length (cm)*	90.5±4.2
Body mass index	22.42±2.0
LEFS score	78.5±2.1
Tegner activity score	6.0±1.0
VAS	0.0±0.0

The 8-camera Vicon motion analysis system (Oxford Metric Ltd, Oxford, UK) was used to capture the three-dimensional coordinates at the frequency of 200 Hz. Participants were unified to wear a pair of running tights and lightweight sports shoes. Three reflective points (diameter 14mm) were attached with adhesive on the left lower limbs over anatomical landmarks including: lateral malleolus, second metatarsal head and calcaneus (Fig. 1-C).

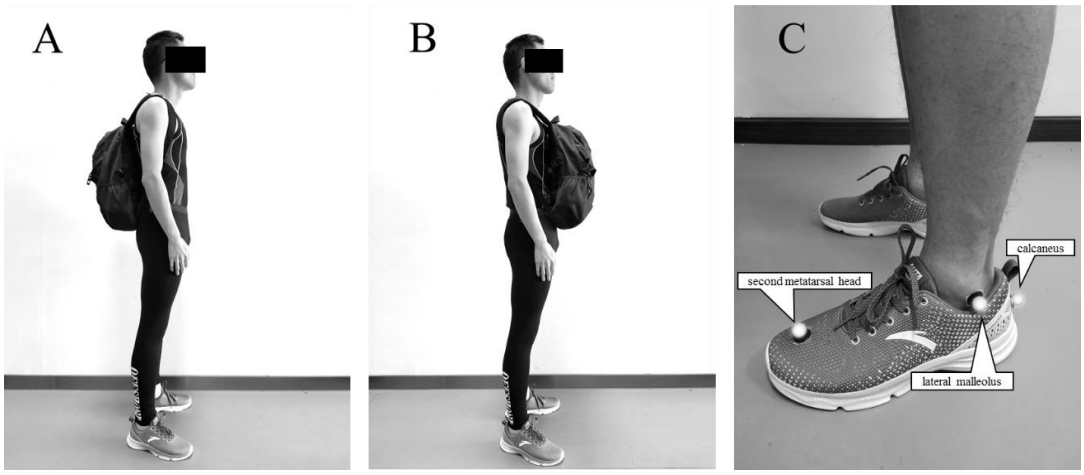

Figure 1. Posterior position (A), anterior position (B) and three reflective points (C)

There were three significant lines extending at 120° increments from the center. The Vicon system was placed around the center to record the motion of marked points. According to the report of Robinson et al [26], each participant practised four times to know the SEBT before the experiment. Coughlan et al [27] indicated that there were no significant differences between right and left lower limbs. Therefore, right lower limb was set as stance limb and left lower limb was the free limb.

Based on the researches of Star Excursion Balance Test before, this study is following the previously experiments of Star Excursion Balance Test [28]. Participant was required to stand in the center of three lines and orient anteriorly. Individual reached with the free limb in the anterior, posteromedial and posterolateral directions as far as possible while stance limb was still at the origin. Then free limb touched down lightly and came back. The process completed continuously without compromising equilibrium. Individuals were asked to place their hands on their hips and not allowed lift the stance heel off the ground during the test.

Weight of loads were set in four conditions: 5%, 10%, 15% and 20% BW (body weight). Each participant performed five times successfully for each loads condition in posterior positions (Fig. 1-A) and anterior positions (Fig.1-B). The loads conditions in two load carriage positions and testing directions were randomised to prevent order effects. A minimum of 45s was allowed between trials to avoid fatigue.

Vicon System recorded the three-dimensional coordinates of the reflective points during the SEBT process. Based on the z-axis of lateral malleolus, second metatarsal head and calcaneus marker point, starting and landing coordinates were founded. (i.e.: Fig.2 shows the landing time of anterior directions when three marker point stop moving during touching).

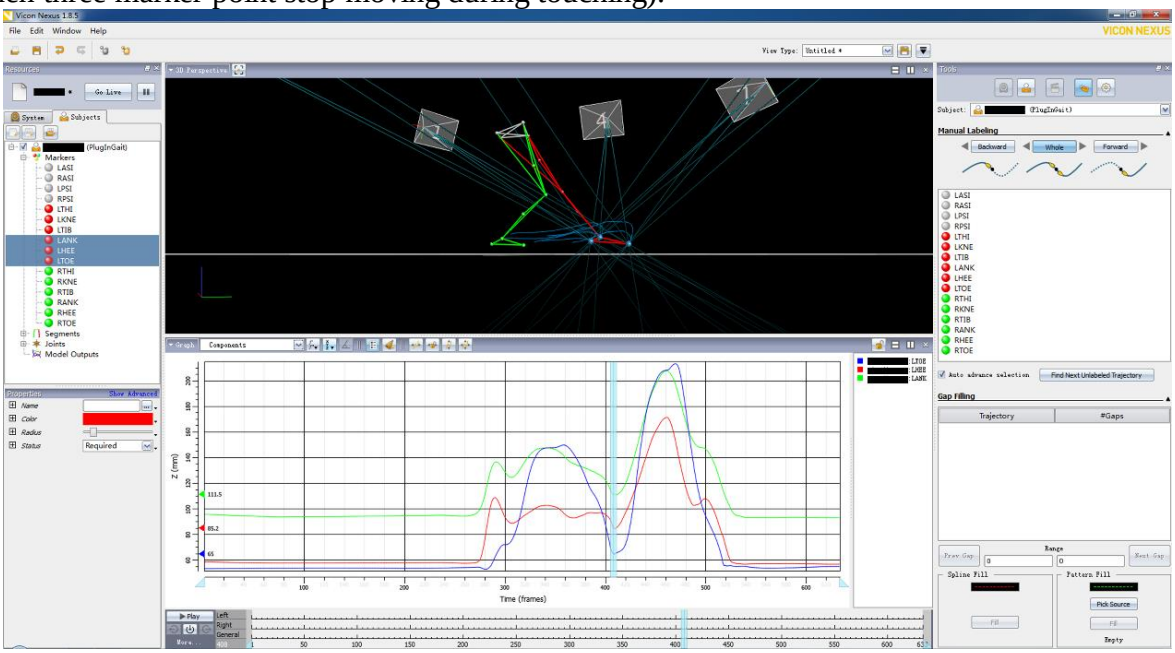

Figure 2. Procedure of Vicon System during finding landing point in anterior direction

Results

The Star Excursion Balance Test is the common method to measure the dynamic balance ability. From Table 2, the normalized excursion distance (%) of SEBT shows significant decreasing trends (all the | ICC | =0.70-0.90, level: Good; p<.01) among three reaching directions during load carriage in posterior position. The results of SEBT show modest decreasing trends (all the | ICC | =0.40-0.70, level: Fair; p<.01) among all the reaching directions when load carriage in anterior position. From the result, dynamic balance reduced with the increase of loads whether anterior or posterior positions. Previous study supported that the work and metabolic cost could increase while added loads. Some studies also reported that higher impact force could overstimulate plantar mechanoreceptors while the

quality of sensory information decrease. This could lead to balance disturbances. These researches all supported that the increase of loads was responsible for the instability.

Table 2 Variation tendency of Star Excursion Balance Test between posterior and anterior positions

	ICC	*P*
	Posterior position	
Anterior reach	-0.724	<.01
Posteromedial reach	-0.762	<.01
Posterolateral reach	-0.788	<.01
	Anterior position	
Anterior reach	-.0629	<.01
Posteromedial reach	-0.487	<.01
Posterolateral reach	-0.701	<.01

Conclusion

Load carriage in anterior and posterior positions show different results in different SEBT normalized excursion distances. The normalized excursion distance decreases as weight of loads increase for three reaching directions. The load carriage in anterior position has higher normalized excursion distance than the posterior position. In addition, with the increase of loads, load carriage in posterior position shows plummet at 5%, while the anterior positions rapid decreases at 20%. This finding suggests that 5% and 20% loads were the optimal weight loads for posterior and anterior positions respectively. Load carriage could cause injury because of overbalance and posterior position might have higher risk of injury than anterior position.

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