BIOMECHANICAL ANALYSIS OF DYNAMIC AND STATIC BALANCE WITH DIFFERENT ARM POSITION

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This study is aimed to explore the balance of participants between arms-free and arms-control conditions with the Star Excursion Balance Test (SEBT) and Romberg's Test. Twenty healthy young males volunteered to participate in the test. Optitrack Optoelectronic system was utilized to capture the spatiotemporal parameters and the three-dimensional coordinates of the lower extremities. Besides, DIERS formetric 4D system was used to analyse the motion amplitude of spine and pelvis. Arms-control could reduce the dynamic balance based on the results of SEBT, and it would increase the static balance in the instability static condition from Romberg's Test. Results of this study have provided information on clinical evaluation using arm position during dynamic and static balance from a biomechanical perspective.

KEYWORDS: the Star Excursion Balance Test; Romberg's Test; tortuosity.

INTRODUCTION: Balance plays a key role in static and dynamic features of human in biomechanics, and it maintains the line of gravity (vertical line from centre of mass) of a body within the base of support with minimal postural sway.

Static balance is mainly based on the Romberg's Test, which was described in the first distribution of Romberg's Test in the early 19th century by Moritz Heinrich von Romberg (Khasnis, & Gokula, 2003). This test could be used for the evaluation of the proprioception of dorsal columns of the spinal cord.

As a normal and valid outcome measure to check dynamic balance, SEBT covers a range of fields including screening, injury identification training and rehabilitation (Eltoukhy et al., 2017). SEBT needs to figure out how far they can reach without losing their balance. This test requires individuals to reach out one lower limb along a significant line while standing on the other lower limb. The distance reached is taken to be related to dynamic balance (Gribble, Hertel, & Plisky, 2012). The farther the distance reached, the better the dynamic postural-control is. As it developed, three directions were recommended to reach out (anterior, posteromedial and posterolateral reaches were preserved) (Hertel et al., 2006).

Due to the lack of unified standard, participants had two kinds of postures during the SEBT and Romberg's Test: people place their hands on their hip and keep arms free during the reaching of lower limbs (Plisky et al., 2006; Smith, Chimera, & Warren, 2015). As the outcome of SEBT research, data is collected based on the operation performed in the test, i.e., people move with both hands on the hips and keep both arms free. For Romberg's Test, subjects just stand with hands by the sides. In addition, most of previous researches did not explicitly state the hand position, instead, photographs of individuals performing the balance tests were provided. Given that upper limb movement can improve performance during the balance, mobility and lower limb strength tests (Objero et al., 2019), it is reasonable to assume that flexibility of upper limb movement during the SEBT could influence outcomes and augment in terms of reaching distance. Even though further research on this part was absent, it was still necessary to investigate the relationship between upper limbs and lower limbs during balance test.

To conclude, this study aimed to investigate the differences in terms of balance control ability between arms-free and arms-control positions. Both the SEBT and Romberg's Test were used to test the dynamic balance. It was hypothesized that arms-free would have a better performance for balance tests.

METHODS: Twenty healthy males volunteered to take part in this study, who are all university students (Age: 20.0±1.0 yr, Height: 175.2±4.9 cm, Weight: 69.2±5.3 kg, BMI: 21.31±2.4).

Participants were free from pain, injury or major surgery in their lower limbs during the past six months and involved in SEBT or Romberg's Test before.

For the SEBT, Optitrack Optoelectronic system (Natural Point Inc., OptiTrack) was used for movement recording with dedicated software. The recording frequency is 120 Hz based on Rizzoli protocol. Participants were required to wear tight shorts and 37 reflective points (diameter of 10mm) were attached on the right and left lower limbs respectively at different key locations. The participant was also required to stand in the centre of three lines and orient anteriorly. Individual should reach out the free limb in the anterior, posteromedial and posterolateral directions as far as possible with the stance limb staying where it was. After that, the free limb should touch down lightly and come back. The process completed continuously without compromising equilibrium (Fig.1). Individuals were not allowed to lift the stance heel off the ground during the test.

For Romberg's Test, DIERS formetric 4D system (GDIERS International) was used for spine movement recording with light-optical scanning. The test includes 4 steps: (i) stand while putting feet together and keeping eyes open; (ii) stand while putting feet together and keeping eyes close; (iii) place right foot in front of the other, heel touching toe (Tandem stand); (iv) place left foot in front of the other, heel touching toe (Tandem stand). The participant remains still in each step under observation for a full period of 30s and DIERS formetric 4D system was used to record all the spine curvatures and pelvic positions. Each participant had to perform three trials, and there are 30s to rest between every trial.

Statistical analysis was performed with SPSS 19.0 software (SPSS Inc., Chicago, IL, USA). In addition, paired-samples t-test was utilized to figure out the differences between arms-free and arms-control. Significance level $p < 0.05$ is defined as a statistical difference.

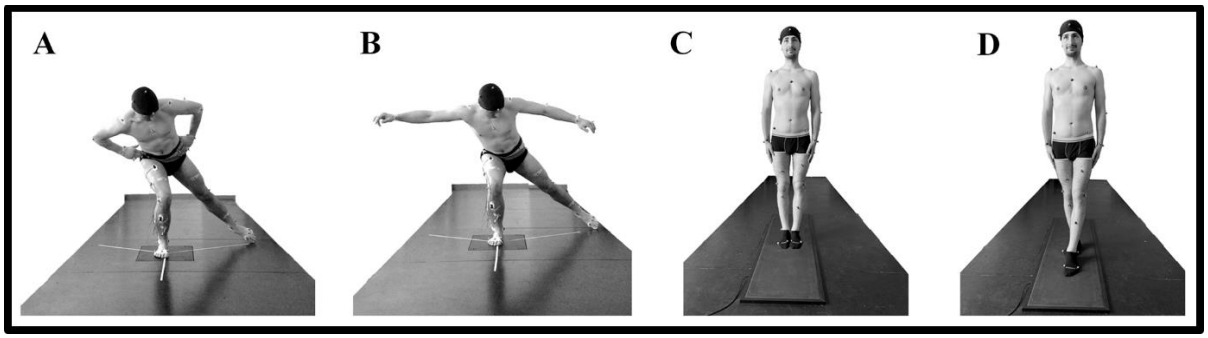

Figure 1: Posteriormedial reach of SEBT and different position of Arms (A; arms-control, B: arms-free); Performance of Romberg's Test with arms-free (C: Normal stand, D: Tandem stand)

RESULTS: The SEBT is the common method to measure the dynamic balance ability. From Table 1, the normalized excursion distance (%) of SEBT shows significant differences (all the | ICC | =0.70-0.90, level: Good; *p*<.01) between arms-free and arms-control in all reaching directions. From the result, the dynamic balance of arms-free was larger than arms-control positions.

Table 1: Variation tendency of SEBT between arms-free and arms-control.

	Arms-Free	Arms-Control	*p*
Anterior reach	0.786	0.614	<.01
Posteromedial reach	0.812	0.725	<.01
Posterolateral reach	0.790	0.682	<.01

Table 2 presents the motion amplitude (VP means Vertebra Prominens; DM means centre between Dimples) between arms-free and arms-control. From the results, it can be seen that there were no significant differences between the two arm positions during normal standing (including eyes open and eyes closed). But for Tandem standing, arms-free showed significantly larger motion amplitude than arms-control (p<.01).

Table 2: The motion amplitude (mm) of Romberg's Test between arms-free and arms-control.

	Arms-Free	Arms-Control	*p*
	Eyes open		
Motion Amplitude (VP)	20.8±2.4	19.3±3.1	>.05
Motion Amplitude (DM)	7.9±1.3	6.3±1.3	>.05
	Eyes closed		
Motion Amplitude (VP)	17.9±3.7	18.7±4.0	>.05
Motion Amplitude (DM)	9.9±2.4	7.3±3.1	>.05
	Left foot forward		
Motion Amplitude (VP)	68.9±10.3	22.8±7.8	<.01
Motion Amplitude (DM)	40.2±9.0	13.5±6.2	<.01
	Right foot forward		
Motion Amplitude (VP)	38.5±6.4	22.9±4.9	<.01
Motion Amplitude (DM)	21.6±4.6	11.1±4.5	<.01

DISCUSSION: The Star Excursion Balance Test and Romberg's Test are the common methods to measure the dynamic and static balance ability, respectively. As anticipated, participants could reach farther when their hands were free to move other than being placed on their hips; in addition, nontrivial differences were detected among normalized posteromedial-, posterolateral- and anterior- scores. These findings suggest a shift in the neuromuscular-control strategies used to perform the SEBT when the upper limbs are restricted compared with free moving, which is supported by empirical evidence of change in dynamic task performance when upper limb motion is restricted (Grisan, Foracchia, & Ruggeri, 2008).

On the other hand, as per the results of Romberg's Test, arm positions had nothing to do with standing no matter eyes are open or not. It indicated that arm position would not affect the balance in normal stand. However, arms-control could reduce the movement of spine and pelvis in instability static condition. It also suggested that arms-control could reduce the risk of falling when the subject was in an instability standing condition.

CONCLUSION: The objective of this study was to analyse the biomechanical characteristics of different arm positions with the SEBT and Romberg's Test. It was found that, compared with arms-free, arms-control would reduce the normalized excursion distance but did not affect the normal standing. Besides, also compared with arms-free, arms-control could improve the static balance ability in instability standing condition. These findings may have great significance in the clinical evaluation of arms function in rehabilitation.

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