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Ankle muscles activation and postural stability with Star Excursion Balance Test in healthy individuals

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ABSTRACT

Introduction: The ankle joint, a part of the kinetic chain of the lower limb, plays a significant role in the maintenance of postural stability during bipedal and unipedal balancing activities. This study aimed to evaluate the neuromuscular control of the ankle joint and the postural stability while executing the Star Excursion Balance Test (SEBT), by recording the EMG activity of the extrinsic ankle musculature and the displacement of the center of pressure (CoP).
Methods: The EMG activity of the tibialis anterior (TA), the peroneus brevis (PB) and the medial and lateral gastrocnemius (GM, GL), along with the anteroposterior and mediolateral displacements (APd and MLd) of CoP as well as the plantar pressure distribution of the supportive lower limb were recorded during reaching to the eight directions of SEBT in 29 healthy, physically active college students (15 males and 14 females; mean ± SD of age 25.6 ± 4.5 yrs.; height: 172.5 ± 8.2 cm; body weight: 67.7 ± 13.6 kg; and BMI: 22.6 ± 2.9 kg/m^2).
Results: The tibialis anterior muscle demonstrated the greatest EMG activity during SEBT, followed by the PB, GL and GM muscles. The increased EMG activity of TA and PB during the execution of all posterior-oriented and lateral directions coincided with a decreased APd of CoP and increased reaching distances. The opposite occurred during the execution of all the anterior-oriented and medial directions. The differences among the directions of SEBT regarding the EMG activity of GL, GM and the mediolateral displacement of CoP were, in general, not significant.
Conclusions: The neuromuscular control of the ankle joint and the associated postural stability during SEBT was highly depended upon the activation level of TA and PB, which should be considered by clinicians and sports specialists when using this test for screening and/or rehabilitation purposes.

1. Introduction

The importance of the ankle joint and the foot in weight-bearing and ambulation is signified primarily by the sophisticated passive (e.g. bones, ligaments) and active (e.g. muscles) anatomical structures, which are involved in their formation, as well as by the interaction between these structures. The latter is usually referred to as neuromuscular control that is the unconscious activation of dynamic restraints occurring in preparation for and in response to joint motion and loading in order to maintain and restore dynamic joint stability (Riemann & Lephart, 2002). This function is of paramount importance as it enables the surrounding musculature to do so during both small perturbations (ankle strategy) of the human body on a firm surface (Guskiewicz & Perrin, 1996; Horak, Nashner,

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& Diener, 1990) as well as during more complex functional tasks and sporting activities (Wikstrom, Tillman, Chmieleiuski, & Borsa, 2006).

The assessment of dynamic stability of lower extremity joints has become a research focus of many clinicians in an attempt to understand better how the body maintains the joint stability during a wide range of activities or how ordinary mechanisms of injury occur (Wikstrom et al., 2006). The majority of researchers have evaluated the components of the sensorimotor system, the outcome of the skeletal muscle activation or some combinations of these factors by measuring variables related to the postural control, muscle activation or joint kinetics/kinematics (Riemann, Myers, & Lephart, 2002). However, the dynamic nature of exercise and sports performance has created the need for assessing the postural stability with sensitive and cost-effective tests that provide reliable information while they challenge optimally the dynamic stability of the joints. A functional task that has been widely used for clinical and research testing purposes mainly in sports is the Star Excursion Balance Test (SEBT), a star-like shape test that requires single-leg squats while reaching as far as possible with the non-stance limb along each one of eight designated lines on the ground spaced 45° apart. This test was described by Gray (1995) as a rehabilitative exercise that was supposed to challenge dynamically body balance. The outcome from the SEBT performance depended on how far the participant's limb could reach (reaching distance) in anterolateral (AL), anterior (A), anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL) and lateral (L) directions while avoiding movements that were considered as errors (e.g. failed to return to the starting position after reaching) during execution of the test (Gribble & Hertel, 2003). The neuromuscular control during the SEBT was reflected on the distance reached in each direction, with an increase in distance reached reflecting a better dynamic postural control (Gribble, Hertel, & Plisky, 2012), while shorter reaching distances were typically associated with mechanical or sensorimotor system constraints (Hoch, Staton, & McKeon, 2011). To date, the muscle activation as a factor contributing to the neuromuscular control during SEBT in the healthy population has been investigated in only a few studies with some of them focusing on the muscles around the knee joint (Earl & Hertel, 2001; Norris & Trudelle-Jackson, 2011). The vastus medialis muscle was found to be equally active between excursions in the A, M and PM directions (Norris & Trudelle-Jackson, 2011) while the greatest EMG activity of vastus medialis oblique and vastus lateralis muscles tended to be presented during the anterior-directed excursions (Earl & Hertel, 2001). The medial hamstrings and biceps femoris demonstrated the greatest activity during the posteriorly-directed excursions (Earl & Hertel, 2001). Despite the profound role of the ankle joint in SEBT, the contribution of the ankle musculature during testing has been poorly investigated. In a study performed by Earl and Hertel (2001), the tibialis anterior muscle presented the greatest activity during all posterior-directed and lateral excursions while the gastrocnemius was found equally active across all directions. Furthermore, postural stability, a key factor for optimal reaching, was examined only in the A, PM and PL directions with the center of pressure area being greater and the center of pressure velocity being lower, during the anterior reach compared to the posterior reaches (Keith, Condon, Phillips, McKeon, & King, 2016).

The lack of evidence necessitates further investigation on the muscle activations and the associated postural stability during SEBT. This information would enable clinicians and/or sports scientists to individualize SEBT execution, at least with regard to the ankle joint, based on the status of trainees (e.g. healthy or injured individuals), the type of injury (e.g. ankle sprains or tenondopathies) or the stage of the rehabilitation progress (e.g. less or more challenged postural stability). The aim, therefore, of this study was to evaluate the neuromuscular control of the ankle joint during reaching in all SEBT's directions, by recording the activity of the extrinsic foot and ankle stabilizers and by quantifying the accompanied postural stability, by means of the CoP displacement and the plantar pressure distribution.

2. Methods

2.1. Sample

Twenty-nine healthy, physically active college students with no systematic involvement in sporting activities at either amateur or professional levels (15 males and 14 females; mean ± SD of age 25.6 ± 4.5 yrs., height: 172.5 ± 8.2 cm, body weight: 67.7 ± 13.6 kg and BMI: 22.6 ± 2.9 kg/m^2) volunteered for the study. All participants were recruited from the School of Physical Education and Sports Science of a major local university. Information about the past/present medical health was selected prior to the investigation. Volunteers (i) who were in pain, not fully weight-bearing or limping, for at least 3 months prior to the study participation, as a result of an acute lower limb or spine injury, (ii) with a history of a significant pathology/trauma or surgery to the lower limb (e.g. chronic ankle instability, fracture) or spine (e.g. disc herniation), (iii) neurological, visual, vestibular, or balance disorders and/or (iv) those who participated in organized sports or performed intensive motor activities of everyday life, were excluded from the study. The study protocol was approved by the University's Human Research Ethics Committee, and each participant signed an informed written consent prior to testing.

2.2. Instrumentation

Disposable, self-adhesive, Ag-AgCl disc-shape (0.9-cm in diameter) electrodes (Red Dot™ type 2223, 3 M Health Care, St Paul, MN), were used to record the EMG activity of tibialis anterior (TA), peroneus brevis (PB), medial gastrocnemius (GM) and lateral gastrocnemius (GL) of the supportive lower limb, using an MP 100 Biopac System (Biopac Systems Inc. CA, USA). These muscles were chosen because (i) they contribute significantly to the stability of the ankle joint, (ii) they are superficial and therefore could be easily accessed with surface electromyography while (iii) the placement of the electrodes on the muscles under investigation provided sufficient distance between them reducing the cross-talk effect. Electrodes were placed on the location described below, with an inter-electrode distance of 2-cm, following the recommendations of Surface Electromyography for the Non-Invasive Assessment of Muscles