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A new approach of the Star Excursion Balance Test to assess dynamic postural control in people complaining from chronic ankle instability

Raphaël Pionnier [a,b], Nicolas Découfour [b], Franck Barbier [a], Christophe Popineau [b], Emilie Simoneau-Buessinger [a,*]

[a] Laboratoire d'Automatique, de Mécanique, et d'Informatique industrielles et Humaines (LAMIH) – UMR CNRS 8201, Université de Valenciennes et du Hainaut-Cambrésis (UVHC), F-59313 Valenciennes, France
[b] Laboratoire d'analyse du mouvement, Centre Hospitalier de la Région de Saint-Omer, F-62505 Saint-Omer Cedex, France

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ABSTRACT

The purpose of this study was to quantitatively and qualitatively assess dynamic balance with accuracy in individuals with chronic ankle instability (CAI). To this aim, a motion capture system was used while participants performed the Star Excursion Balance Test (SEBT). Reached distances for the 8 points of the star were automatically computed, thereby excluding any dependence to the experimenter. In addition, new relevant variables were also computed, such as absolute time needed to reach each distance, lower limb ranges of motion during unipodal stance, as well as absolute error of pointing. Velocity of the center of pressure and range of variation of ground reaction forces have also been assessed during the unipodal phase of the SEBT thanks to force plates. CAI group exhibited smaller reached distances and greater absolute error of pointing than the control group ($p < 0.05$). Moreover, the ranges of motion of lower limbs joints, the velocity of the center of pressure and the range of variation of the ground reaction forces were all significantly smaller in the CAI group ($p < 0.05$). These reduced quantitative and qualitative performances highlighted a lower dynamic postural control. The limited body movements and accelerations during the unipodal stance in the CAI group could highlight a protective strategy. The present findings could help clinicians to better understand the motor strategies used by CAI patients during dynamic balance and may guide the rehabilitation process.

1. Introduction

Lateral ankle sprain is one of the most frequent sports related injuries and it can represent up to 45% of injuries in sports with high risk such as basketball [1]. This traumatic mechanism can happen during specific sport movements [2] and even during activities of daily living [3]. After a first ankle sprain, involving collateral lateral ligaments, residual symptoms can appear with an occurrence that could be estimated up to 73% [4,5]. Among these residual symptoms, repeated episodes of lateral instability could appear and induce recurrent sprains [6]; these episodes often define chronic ankle instability (CAI). This pathology is mainly characterized by ankle “giving-way”, which corresponds to an ankle joint disrobement during its loading [5], as well as by an alteration of the proprioceptive system [5,6] that can contribute to a decline in neuromuscular control and induce an altered postural control [7]. In order to properly diagnose CAI, self-reported questionnaires, such as Foot and Ankle Ability Measure (FAAM) and FAAM Sport [8] are often used to complete the subjective information given by the feeling of an ankle “giving-way”.

Postural control may be classified as either static, with the aim to maintain a base of support with minimal movement, or dynamic, with the aim to maintain a stable base of support while completing a prescribed movement. Altered static postural control in the presence of CAI has not been systematically demonstrated thanks to classical measures such as center of pressure velocity [9–11]. It was hypothesized that this absence of consensus could be explained by a lack of sensitivity of these measures and that is why more efficient variables should be used to better characterize CAI during static balance assessment [12,13]. Although dynamic postural control has already been investigated in this population [4,12,14–19], this ability should be even more precisely studied,

* Corresponding author at: Laboratoire d'Automatique, de Mécanique et d'Informatique industrielles et Humaines (LAMIH) – UMR CNRS 8201, Université de Valenciennes et du Hainaut Cambrésis (UVHC), Le Mont Houy, F-59313 Valenciennes Cedex 09, France. Tel.: +33 3 27 51 14 60; fax: +33 3 27 51 13 16.
E-mail address: emilie.simoneau@univ-valenciennes.fr (E. Simoneau-Buessinger).

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especially because more complex functional tasks may allow for better identification of postural deficits. A common test used to quantify dynamic balance is the Star Excursion Balance Test (SEBT) [20], which goal is to maintain single leg stance while reaching maximal distance with the extremity of contralateral limb in each direction of a star materialized on the floor. This test is a series of eight lower-extremity-reaching tasks purported to be more useful and relevant in identifying lower extremity functional deficits than tests involving only quiet standing. The SEBT indeed requires both lower extremity balance, strength, coordination, flexibility and proprioception [21] and is mainly used as a functional screening tool to assess dynamic stability, monitor rehabilitation progress, assess deficits following a lower extremity injury, identify athletes at high risk for lower limb injury [21,22], and identify chronic ankle instability [4].

The metrological properties of the SEBT can however be discussed because since this balance test is dynamic and manually assessed, difficulty can occur in attempting to accurately measure the farthest reached point [4,14,15], which can constitute a strong limitation of the SEBT use. Besides, the SEBT is so far limited to measurements obtained only in a position reached at the end of the investigated movements. Beyond these observations, clinicians need further information to properly understand motion dysfunctions related to CAI. Investigations of generated movements during dynamic balance tests are thus necessary. Within this framework, a quantitative and qualitative method for measuring dynamic balance can be developed. A more accurate and reliable way to assess reach distances would be then to use an optoelectronic cameras system, which is becoming more and more widespread in clinical centers and motion analysis laboratories. In addition, the use of such equipment also allows to investigate how the movement is performed and, notably, can give information about (1) the time needed to reach the target, (2) the accuracy of the pointing task and (3) the range of motion (ROM) of the lower limb joints.

The main aim of the present study was to assess dynamic balance with accuracy in CAI sufferers thanks to the contribution of movement analysis laboratory tools. It could be assumed that a good dynamic postural stability would imply a greater reached distance as well as a longer time to perform the task and would induce a better pointing accuracy. Use of optoelectronic cameras and force platforms could also increase the knowledge about the motor strategy used by CAI sufferers during SEBT procedure.

2. Methods

2.1. Participants

A total of 34 adults were recruited for this study: 17 adults with unilateral CAI (7 women and 10 men) constituted the CAI group (age 27.8 ± 8.4 years; height 1.73 ± 0.09 m; body mass 74.0 ± 19.5 kg) and 17 adults without CAI (5 women and 12 men) constituted the control (CTRL) group (age 28.8 ± 9.8 years; height 1.76 ± 0.08 m; body mass 70.9 ± 11.5 kg). Each participant had a specific medical consultation with a sport medicine doctor to assess instability degree of both ankles thanks to specific examination of the lower limbs. Participants were also asked to complete the FAAM and FAAM Sport questionnaires to assess their subjective instability felt during activities of daily living and during sports activities, respectively. The clinical examination also allowed excluding neurologic pathologies. In addition, each participant had to report no history of bone fracture or surgery of the lower limbs in the past 4 years. Further exclusion criteria were ankle pain and swelling. To be included in the CAI group, participants had to report a history of at least one sprain older than 4 months at the unstable ankle as well as a history of at least 3 episodes of "giving-way" on the same ankle in the past year. To be included in the CTRL group, participants had to be free of severe ankle sprain and had to never report any feeling of ankle "giving-way". Since unilateral instability affected 13 dominant limbs, defined as the limb used to kick a ball, and 4 non-dominant limbs in the CAI group, 13 dominant limbs and 4 non-dominant limbs have been examined in the CTRL group. In each group, there were 5 left limbs and 12 right limbs investigated. These limbs corresponded to the "stance limb" during the SEBT. All volunteers gave written informed consent to participate in the study and all procedures complied with the Declaration of Helsinki and were approved by the local Ethics Committee.

2.2. Materials

A motion capture system (Vicon Motion Systems Ltd., Oxford, UK) with eight cameras (Vicon® MX40) captured the spatial location of retro-reflective markers with a sample rate of 100 Hz. Eight retro-reflective markers were used to materialize the extremities of an 8-pointed star, placed at 1.5 m of the barycenter of the star (BARY). These markers defined the anterior (A), antero-medial (AM), medial (M), postero-medial (PM), posterior (P), postero-lateral (PL), lateral (L) and antero-lateral (AL) targets (Fig. 1). The reaching directions were actually named based on the stance limb. A 30 retro-reflective markers biomechanical model was used in this study to quantify lower limb kinematics. It was based on ISB recommendations [23] and it allowed to quantify hips, knee and ankle kinematics in sagittal, frontal and transverse planes. An AMTI® force-plate (AMTI; Watertown, MA), with a sample rate of 100 Hz, was used to quantify spatio-temporal and dynamic parameters under foot during the unipodal stance phase of the experimental procedure.

2.3. Procedures

Once participants were equipped with all the markers in the movement analysis laboratory, they had to perform the SEBT. It began in a bipodal stance with the stance foot placed on the BARY. Then, the non-tested foot left the floor. Consequently, participants stood in a single limb stance on the tested-limb. While keeping balance on the tested limb, objectives for the participant were twofold: (1) to point with the extremity of the non-tested foot (touchpoint) as far as possible and (2) to align as precisely as possible the retro-reflective marker placed on the head of the third metatarsal bone (META) with the target marker defining the tip of

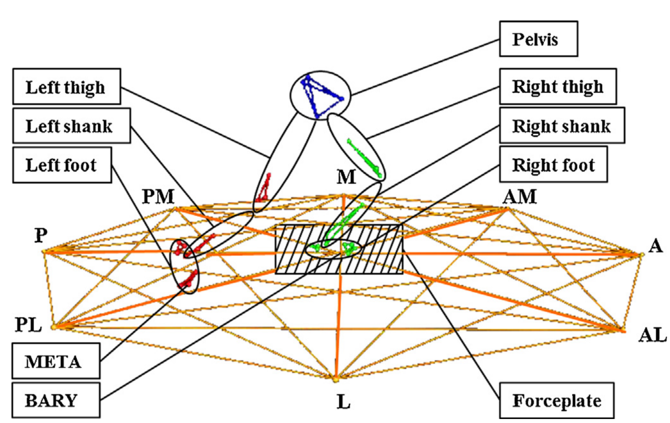

Fig. 1. Set up configuration of the Star Excursion Balance Test (SEBT) using motion capture. Representation of the assessment of the right ankle in the postero-lateral (PL) direction. Image partly obtained from Nexus® software. Other directions of the star: A: anterior, AM: antero-medial, M: medial, PM: postero-medial, P: posterior, L: lateral and AL: antero-lateral; BARY: barycenter of the star, META: head of the third metatarsal bone.