Human Movement Science 58 (2018) 239–247

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Influence of rest interval on foot-tibia coordination with chronic ankle instability during the Star Excursion Balance Test

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ARTICLE INFO

Keywords:
Vector coding
Coupling angle
The Star Excursion Balance Test
Kinematics

ABSTRACT

The purpose of this study was to determine whether different rest intervals affect performance on the Star Excursion Balance Test (SEBT) associated with chronic ankle instability (CAI) and whether foot-tibia coordination can be associated factors that may help discriminate between individuals with and without CAI during the SEBT.

Participants included forty-eight individuals with (n = 24) and without CAI (n = 24). Subjects completed 3 trials in each of the 3 reach directions (anteromedial, medial, posteromedial) in random order. A total of three visits were required to complete the 3 rest interval conditions (10, 20, 40 s). Coupling angles (CA) of tibial internal rotation/dorsiflexion (TIR/DF) and tibial internal rotation/eversion (TIR/EV) were calculated and compared between groups in each direction for each rest interval.

Individuals with CAI showed greater CAs of TIR/DF in the M direction ($p = 0.01$) and of TIR/EV in the P direction ($p = 0.04$) than healthy individuals in 20 s rest interval time. Overall, joint CAs were different between healthy individuals and those with CAI during the SEBT regardless of rest interval. Based on these results, rest interval and a natural result of CAI could alter ankle joint coordination in comparison of healthy individuals when performing the SEBT.

1. Introduction

Chronic ankle instability (CAI) is a residual symptom of ankle sprains and is defined as a feeling of “giving way” at the ankle and the presence of recurrent ankle sprains (Yeung, Chan, So, & Yuan, 1994). Individuals with CAI exhibit balance deficits and these deficits have been proposed as a risk factor for subsequent ankle sprains. (Riemann, 2002) Chronic ankle instability can be partially characterized by decreased neuromuscular control and function (Riemann, 2002). The Star Excursion Balance Test (SEBT) is a common clinical test that estimates neuromuscular function in individuals with CAI by measuring maximum reach distance (Hertel, Braham, Hale, & Olmsted-Kramer, 2006).

Previous researchers have examined specific lower extremity kinematics as factors that may impact decreased maximum reach distance in individuals with CAI during the SEBT (Fullam, Caulfield, Coughlan, & Delahunt, 2014; Robinson & Gribble, 2008a). Specifically, these previous studies have primarily focused on discrete multiple plane movement of the ankle, knee, and hip, and trunk (Fullam et al., 2014; Robinson & Gribble, 2008a). However, because of the multi-joint coordination that occurs normal human movement, it is important to understand coupled movements during performance of the SEBT. Coordination can be measured

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https://doi.org/10.1016/j.humov.2018.02.009
Received 27 August 2017; Received in revised form 15 February 2018; Accepted 16 February 2018
Available online 12 March 2018
0167-9457/

partially by ankle dorsiflexion (sagittal plane) at the talocrural joint with ankle eversion (frontal plane) and tibial internal rotation (transverse plane) at the subtalar joint during passive pronation (Hubbard & Hertel, 2006; Richie, 2001). Individuals with CAI demonstrate limited dorsiflexion range of motion. Because of this limitation and the fixation of the foot on the floor during single leg standing activities, there is likely a greater need for compensatory motion of tibia (Hubbard & Hertel, 2006; Richie, 2001) Therefore, coordination between sagittal plane motion of the foot and transverse plane motion of tibia may be important in understanding the deficits in performance of the SEBT.

Coordination relationships between the foot and tibia have been considered as factors that influence neuromuscular function under a variety of conditions (Ferber, Davis, & Williams, 2005; Williams, McClay, & Hamill, 2001). Specifically, individuals with CAI demonstrate more antiphasic coupling of the ankle and lower leg during terminal swing indicating that foot inversion occurs faster than tibial external rotation during walking and jogging (Drewes et al., 2009). This likely leads to poor coordination at initial contact and risk of lateral strain on the foot and ankle. Moreover, a study by Herb et al., showed that individuals with CAI demonstrated greater relative rearfoot motion compared with the shank motion during walking and jogging. (Herb et al., 2014) This may present a more rigid sensorimotor control at the ankle in individuals with CAI compared to those without CAI (Herb et al., 2014). Further, low-arched runners demonstrate a higher eversion to tibial internal rotation ratio compared to high-arched runners (Nawoczenski, Saltzman, & Cook, 1998). Consequently, it has been suggested that high-arched runners report a greater incidence of lateral ankle sprains compared to low-arched runners as a result of these coordination differences (Williams et al., 2001). These disruptions in the normal relationship between dorsiflexion, eversion and internal rotation (pronation) in the rearfoot complex are therefore responsible for discoordinated movement further up the chain and may be contributors to injury, both chronic and acute. Therefore, it is important to understand how a disruption in lower extremity coupling during simple functional tests such as the SEBT may contribute to ankle injuries. However, there are no studies that consider lower extremity coordination relationships as factors that discriminate between individuals with and without CAI during the SEBT.

Vector coding (VC) technique is one method utilized to measure continuous joint coordination during a specific targeted motion (Sparrow, Donovan, van Emmerik, & Barry, 1987; Van Emmerik, Rosenstein, McDermott, & Hamill, 2004; Whiting & Zernicke, 1982). Vector coding utilizes an angle-angle diagram constructed from the movement of two (in this case: adjacent) segments or joints of interest (Grieve, 1969). Specifically, these angle-angle diagrams establish a coupling angle that indicates the amount of angular movement that occurs between distal and proximal segments during performance of purposed tasks (Heiderscheit, 2000; Sparrow et al., 1987; Van Emmerik et al., 2004; Whiting & Zernicke, 1982). To date, VC analysis has not been employed in individuals with CAI in an attempt further understand lower extremity coordination and dynamic postural control during the SEBT.

Few studies utilizing the SEBT have employed rest intervals of 10 or 15 s between trials (Hertel et al., 2006; Hertel, Miller, & Denegar, 2000; Linens, Ross, Arnold, Gayle, & Pidcoe, 2014). However, there is no consistent or accepted norms of rest interval on performance of the SEBT. Thus, using variable rest times by clinicians could affect the results and reliability of the SEBT. Rest interval is strongly associated with enhancement of performance in previous studies. For example, shorter rest interval times resulted in decreased sprint performance and in decreased muscle work performance during elbow flexion in comparison of longer rest interval times. These studies suggested that the results in decreased performance were due to lack of recovery time resulting in fatigue (Abt, Siegler, Akubat, & Castagna, 2011; Nogueira et al., 2012). Moreover, Gribble et al., demonstrates that CAI individuals displayed smaller reach distance and knee-knee flexion angles compared with individuals without CAI in fatigued condition (Gribble, Hertel, Denegar, & Buckley, 2004). Therefore, Rest interval times may also alter kinematics during the SEBT which could eventually affect performance of the task. However, there are no current studies that have examined the relationship between rest interval and foot-tibia coordination on the SEBT in individuals with and without CAI. Therefore, our purpose was to determine whether different rest intervals impact foot-tibia coordination and whether foot-tibia coordination values discriminate between healthy individuals and those with CAI during the SEBT. We hypothesize that different rest intervals would result in altered foot-tibia coordination and that foot-tibia coordination would be different between healthy individuals and those with CAI during the SEBT.

2. Methods

2.1. Participants

Two populations were included in the study. 24 subjects with CAI (age: 22.7 ± 1.6 years, height: 170.9 ± 7.2 cm, mass: 65.4 ± 7.6 kg) and 24 uninjured subjects (age: 21.9 ± 2.3 years, height: 168.4 ± 6.6 cm, mass: 68.9 ± 6.5 kg). Each population was composed of 12 male and 12 female participants. To determine the eligibility of CAI group, subjects had to meet the following inclusion criteria: (1) physical activity defined as at least 3 h per week of activity for purpose of being healthy (2) a history of at least 1 significant ankle sprain which requires that the initial sprain must have occurred at least 12 months prior to the study enrolment, inflammatory symptoms such as pain or swelling, and at least one interrupted day of desired physical activity, (3) multiple episodes of the ankle giving way within the past 6 months, and/or (4) feeling of instability, (5) No history of previous surgeries to the musculoskeletal structures or of a fracture in the lower extremity, and (6) no prior structured, supervised or extensive rehabilitation or balance training (Gribble et al., 2014). A questionnaire including the definition of an ankle sprain ("an acute traumatic injury to the lateral ligament complex of the ankle joint as a result of excessive inversion of the rear foot or a combined plantar flexion and adduction of the foot") and inclusion criteria was provided to the subjects to determine eligibility for participation in this study (Gribble et al., 2014). The Cumberland Ankle Instability Tool (CAIT) was used in addition to confirm validated ankle instability. Individuals with a score of more than 25 of the CAIT were excluded from CAI group in this study (Wright et al., 2013). All subjects gave written informed consent approved by the University Institutional Review Board.