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Contributing factors to Star Excursion Balance Test performance in individuals with chronic ankle instability

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ABSTRACT

The purpose of this study was to determine the contributions of strength, dorsiflexion range of motion (DFROM), plantar cutaneous sensation (PCS), and static postural control to Star Excursion Balance Test (SEBT) performance in individuals with chronic ankle instability (CAI). Forty individuals with CAI completed isometric strength, weight-bearing DFROM, PCS, static and dynamic balance assessments. Three separate backward multiple linear regression models were calculated to determine how strength, DFROM, PCS, and static postural control contributed to each reach direction of the SEBT. Explanatory variables included dorsiflexion, inversion, and eversion strength, DFROM, PCS, and time-to-boundary mean minima (TTBMM) and standard deviation (TTBSD) in the medial–lateral (ML) and anterior–posterior (AP) directions. Criterion variables included SEBT-anterior, posteromedial, and posterolateral directions. The strength of each model was determined by the R^2-value and Cohen's f^2 effect size. Regression models with an effect size ≥0.15 were considered clinically relevant. All three SEBT directions produced clinically relevant regression models. DFROM and PCS accounted for 16% of the variance in SEBT-anterior reach ($f^2 = 0.19$, $p = 0.04$). Eversion strength and TTBMM-ML accounted for 28% of the variance in SEBT-posteromedial reach ($f^2 = 0.39$, $p < 0.01$). Eversion strength and TTBSD-ML accounted for 14% of the variance in SEBT-posterolateral reach ($f^2 = 0.16$, $p = 0.06$). DFROM and PCS explained a clinically relevant proportion of the variance associated with SEBT-anterior reach. Eversion strength and TTB ML explained a clinically relevant proportion of the variance in SEBT-posteromedial and posterolateral reach distances. Therefore, rehabilitation strategies should emphasize DFROM, PCS, eversion strength, and static balance to enhance dynamic postural control in patients with CAI.

1. Introduction

Ankle sprains are common in physically active populations. The incidence of ankle sprains in military and select athletic cohorts can be up to twenty-seven times greater than reported in the general population [1]. Approximately 30% of individuals who suffer an initial lateral ankle sprain develop chronic ankle instability (CAI) [2]. CAI is a condition defined as a history of at least one ankle sprain resulting in one or more recurrent sprains combined with feelings of joint instability and occasionally pain [3]. CAI has been associated with both short- and long-term sequelae; thus requiring clinicians and researchers to develop a better understanding of the factors that contribute to this condition [3].

Individuals with CAI have commonly displayed dynamic postural control deficits [4]. These deficits have often been identified using a clinical assessment known as the Star Excursion Balance Test (SEBT) [4]. The SEBT requires an individual to establish and maintain a stable base of support during single-limb stance while performing a maximal reach excursion with the contralateral limb [5]. Shorter reach distances are indicative of dynamic postural control deficits which are typically associated with a combination of mechanical or sensorimotor system constraints [6]. To date, contributing factors to SEBT performance

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in individuals with CAI have not been thoroughly examined. Terada et al. [7] identified dorsiflexion range of motion (DFROM) and self-perceived stiffness as significant contributors to SEBT-anterior reach distance; however, range of motion and self-reported outcomes did not significantly influence the other reach directions of the SEBT. CAI has been associated with impairments beyond range of motion and self-reported outcomes suggesting other factors may influence dynamic postural control in these individuals. Identifying impairments that contribute to normalized SEBT performance may provide insight into the dynamic postural control deficits experienced by individuals with CAI.

CAI has been associated with a combination of mechanical and functional impairments [3]. Documented impairments include but are not limited to arthrokinematic restrictions [8], pathologic joint laxity [9], and sensorimotor deficits [2]. The sensorimotor impairments associated with CAI range from altered motoneuron pool excitability [10,11] and increased peroneal reaction time [12] to decreased joint reposition acuity [13]. However, many of these deficits may be impractical to collect in clinical settings, or they may not be associated with clear intervention strategies. Conversely, ankle eversion and inversion strength, DFROM, static postural control, and plantar cutaneous sensation (PCS) deficits have been observed in individuals with CAI using common clinical and laboratory assessments and have been successfully addressed through various rehabilitation interventions [14–17]. Examining the contribution of strength, DFROM, static postural control, and PCS to dynamic postural control performance may help identify a core group of modifiable impairments that are important for functional movements in these individuals.

Understanding the relationships between SEBT performance and strength, DFROM, static postural control, and PCS may help to elucidate meaningful pathways toward developing evidence-based rehabilitation strategies to address dynamic postural control deficits in individuals with CAI. Therefore, the purpose of this study was to determine the extent to which strength, DFROM, static postural control, and PCS contribute to SEBT performance in individuals with CAI. We hypothesized that SEBT-anterior, posteromedial, and posterolateral reach directions would each have their own unique set of explanatory variables.

2. Methods

2.1. Participants

Forty physically active adults (males = 13, females = 27) with self-reported CAI [18] participated in this cross-sectional study (Table 1). Participants were recruited from a large public university over a one-year period. These participants were part of a larger study that examined contributions of functional and mechanical impairments to health-related quality of life in individuals with CAI [19]. Prior to enrollment, all participants provided written informed consent which was approved by the University's Institutional Review Board. Participants were included if they reported a history of one or more ankle sprains, at least two episodes of "giving way" in the last three months, a score <24 on the Cumberland Ankle Instability Tool (CAIT), and ≥5 "yes" answers on the Ankle Instability Instrument (AII) [20]. Participants were excluded if they had experienced any lower extremity injuries in the last six months, reported a history of lower extremity surgery, or had a neurological disorder that would influence balance. Individuals were considered physically active if they reported greater than four out of ten on the National Aeronautics and Space Administration (NASA) Physical Activity Scale. If a participant reported bilateral ankle instability, the ankle with the lower CAIT score was tested.

Table 1
Participant characteristics and inclusionary measurements ($n = 40$).

Participant characteristics	Mean ± SD
Age (years)	23.25 ± 4.76
Height (cm)	168.84 ± 9.20
Mass (kg)	72.04 ± 14.36
Cumberland Ankle Instability Tool	16.33 ± 4.55
Ankle Instability Instrument	6.60 ± 1.41
National Aeronautics and Space Administration Physical Activity Scale	6.70 ± 1.71
Previous ankles sprains	3.45 ± 1.65
Episodes of giving way in the past three months	5.88 ± 7.91
Time since last significant ankle sprain (months)	23.64 ± 22.75

2.2. Procedures

Participants reported to the laboratory for a single testing session to complete isometric strength testing, the Weight-Bearing Lunge Test (WBLT), PCS, static and dynamic postural control assessments. Upon completion of the consent document, participants completed the CAIT, AII, a Balance History Questionnaire, and the NASA Physical Activity Scale. Prior to testing, height, mass, and true leg length (i.e., anterior superior iliac spine to the inferior border of the medial malleolus) measures were obtained and recorded. All testing procedures were performed barefoot and counterbalanced to avoid interactions. Three test trials for each assessment were recorded and averaged for analyses.

Dorsiflexion, inversion, and eversion isometric strength were measured using a handheld dynamometer (MicroFET2™, Hoggan Health Industries, Inc., West Jordan, UT). Using the "make" test, participants were positioned supine and asked to ramp into a 3–5 s maximum effort contraction against the overpowering resistance of the examiner. All procedures were consistent with those previously established by Kelln et al. [21]. The same investigator performed all strength assessments. Intraclass correlation coefficient (ICC) values for handheld dynamometry in the dorsiflexion, inversion, and eversion directions have ranged from 0.77 to 0.86 [21].

To estimate DFROM participants performed the WBLT using the knee-to-wall principle as described by Vicenzino et al. [22]. The opposite extremity was positioned behind the test foot to maintain stability during the test. Participants were instructed to lunge toward the wall until the anterior knee made contact while keeping the heel in contact with the floor. A tape measure on the floor was used to measure the furthest distance, in centimeters, the foot could be positioned away from the wall while maintaining proper testing position. In this test, a further distance from the wall indicated greater DFROM. The WBLT has displayed excellent inter-rater and intra-rater reliability (ICC = 0.97–0.99) [23].

Semmes-Weinstein Monofilaments (SWM) (Texas Medical Design, Inc., Stafford, TX) were used to assess PCS. Using a 4-2-1 stepping algorithm [24], SWM were applied at the center of the heel. Participants were instructed to verbally indicate when they detected a monofilament. The lowest weight detected was recorded as the participant's PCS. Lower detection thresholds indicated better PCS.

Instrumented measures of static postural control were collected using an Accusway Plus force plate (AMTI; Watertown, MA) which captured center of pressure data at a 50 Hz sampling rate. During each static postural control trial, participants balanced on a single-limb with eyes-closed for 10 s. To begin, the involved limb was centered on the force plate and participants were instructed to keep their hands on their hips. The trial was repeated if a participant lost balance, opened their eyes, or touched their free limb down at any point during the trial. Center of pressure data