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Reliability and responsiveness of gait initiation profiles in those with chronic ankle instability

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ABSTRACT

Individuals with chronic ankle instability (CAI) have demonstrated deviations in gait initiation (GI) compared to healthy individuals. However, the intersession reliability of GI measures remains unknown in this population. The objective of this study was to determine the reliability and responsiveness of GI measures between two testing days in those with CAI. Twelve individuals with CAI volunteered. Participants performed barefoot GI on a force plate which captured center of pressure (COP). Data was collected on two separate occasions separated by one week. The GI profile was separated into three phases (S1, S2, and S3). S1 began from the deviation of normal balanced standing to the most posterolateral displacement under the stepping limb. S2 began from the end of S1 to the maximum medial position under the stance foot. S3 began at the end of S2 and continued until the vertical ground reaction force dropped below 100 N. COP displacement (cm) was calculated as the sum of resultant vectors of the medial-lateral and anterior-posterior excursions for adjacent COP data points within each phase. The averages of 5 trials were used for analyses. Intraclass correlation coefficients (ICC(2,5)), standard error of measurement, and minimum detectable change (MDC) were calculated to determine reliability and responsiveness. S1, S2, and S3 displacement values were highly reliable between days (ICC (2,5) $\geq$0.76) with the exception of anterior-posterior S1 and medial-lateral S3. MDC values were relatively small (0.6–2.2 cm). GI can be reliably assessed in those with CAI which is important for identifying interventions to alter GI profiles in these individuals.

1. Introduction

Ankle sprains are common injuries in physically active populations [1]. Up to 75% of individuals who suffer a lateral ankle sprain may develop chronic ankle instability (CAI) [2]. CAI is characterized by an initial ankle sprain followed by repetitive future ankle sprains and the recurrent sensation of “giving way” [3]. Individuals with CAI are more likely to experience long-term consequences such as post-traumatic ankle osteoarthritis [4] and decreased health-related quality of life [5,6]. Therefore, CAI is a common sequelae of lateral ankle sprains with implications that extend beyond the disability associated with acute bouts of joint trauma.

Several functional and mechanical impairments have been identified as contributing factors to CAI including alterations in sensorimotor function [7,8]. Sensorimotor alterations include deficits in postural control and deviations in gait [3]. The sensorimotor alterations associated with CAI are thought to be caused by alterations in the feedback mechanisms of motor control because of damage to afferent receptors located in the ankle joint. However, alterations in single-limb stance postural control have been identified in the uninjured limb [9] of individuals with unilateral CAI suggesting there may be alterations in feed-forward mechanisms in these patients. Additionally, individuals with CAI have demonstrated predictable muscle recruitment during differing conditions where healthy individuals adapted to the conditions by recruiting different muscles [10]. These alterations were identified during a transition from a double limb stance to single limb stance which may be similar to the transition that occurs during GI. Alterations in feed-forward mechanisms of motor control would indicate that those with CAI may exhibit detrimental changes in the central organization of executing a movement goal.

Alterations in the central organization of movement in individuals with CAI are supported by a study [11] which identified

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deviations in the gait initiation (GI) profile of these individuals. GI is the transition from a stable stance to a stable state of walking and has been thought of as a measure of postural control and global functioning of the feed-forward mechanism of the sensorimotor system. The goals of the initial phase of GI are to generate forward momentum and propulse the center of mass toward the initial stance limb. Hass et al. [11] determined that individuals with CAI tend to have less of a posterolateral shift in center of pressure (COP) at the beginning of GI. The initial decreased shift towards the posterolateral direction at the beginning of GI declines naturally with age and disability, but may also be decreased in individuals with a postural control deficit [12–14]. Individuals with CAI also demonstrate less of a shift towards the stance foot when shifting weight from the step foot to the stance foot [11]. This decrease could be indicative of a reduction in lateral stability in these individuals. Decreases in both of these shifts represent a more constrained sensorimotor system and alterations in the central organization of movement where healthy individuals may be able to better adapt and cope to different demands utilizing varying options to complete the movement goal.

Although GI impairments have been identified in individuals with CAI, the reliability of this assessment has not been examined in this population. Establishing the reliability of GI is essential to determine if changes in this aspect of function can be captured over time and following clinical interventions. Therefore, the purpose of this study is to determine the intersession reliability and responsiveness of GI measures in those with CAI.

2. Methods

2.1. Participants

Twelve participants with self-reported CAI (6 females and 6 males: age = 27.4 ± 4.5 years, height = 175.4 ± 10.8 cm, mass = 78.4 ± 12.1 kg) volunteered to participate. To be included, Participants reported a history of at least one previous ankle sprain and 2 episodes of a "giving way" sensation in the previous 3 months. Participants had to report a decrease in function due to their history of ankle sprains by scoring ≤90% on the Foot and Ankle Ability Measure (FAAM) and ≤80% on the FAAM-Sport. The means and standard deviations for these measures are included in Table 1. Exclusion criteria included a history of ankle sprain within the past 6 weeks, lower extremity surgery or fracture, and balance or neurological disorders. In cases of bilateral CAI, the limb with the greatest functional loss on the FAAM was included. All participants provided written informed consent in compliance with the institutional review board.

2.2. Instrumentation

Participants performed barefoot GI on a dual belt treadmill customized with embedded force plates (Model TM-09-P, Bertec Corp.; Columbus, OH, USA) which captured COP data at 500 Hz. Kinetic data were collected using Cortex v1.0 software (Motion Analysis Corporation, Santa Rosa, CA, USA).

Table 1
Subject demographics.

Measure	Mean ± SD
Total ankle sprains	5.3 ± 5.5
Episodes of giving way over past 3 months	8.4 ± 7.4
FAAM	86.8 ± 11.1
FAAM sport	74.2 ± 18.9

2.3. Procedures

Participants completed two data collection sessions separated by 7 days (Session-1, Session-2). Between sessions, participants were instructed to maintain normal activities. During each data collection session, GI was assessed on both limbs. To assess GI, participants were instructed to stand with their feet shoulder width apart on a force plate. An audible cue was given when the participant appeared ready. Participants were instructed to take their initial step with a predetermined limb and then continue to walk down a stationary 3 m walkway at a self-selected speed. Participants performed 1–2 practice trials to become oriented with the GI protocol in each session. The subjects performed 10 trials on each limb. The five trials with the closest stance width during each session with the involved limb serving as the stance limb were used for analysis.

2.4. Data reduction

The 3 phases of the GI profile were identified for each trial (Fig. 1). The first phase (S1) began with the subject receiving an audible cue to initiate walking and ended with the COP transitioning to the most posterior and lateral position. The second phase (S2) was identified by the shift in COP towards the initial stance foot and ended when the COP transitioned to the most medial position. The third phase (S3) was characterized by the COP moving in the anterior direction until toe off occurred identified by reaching the 100 N threshold [11].

The COP displacement in the anteroposterior (AP), mediolateral (ML), and resultant planes was calculated for all 3 phases of GI. To examine the frequency spectrum of the GI profile, a Fast Fourier Transformation (FFT) was used in order to determine the frequency profile for the ML, AP, and resultant displacements. The majority of the information was found below 10 Hz. Therefore, a 4th order zero-lag low-pass Butterworth filter with a cutoff frequency of 10 Hz filtered all COP data.

2.4.1. Calculation of COP displacement during gait initiation

Eq. (1) was used to determine the COP_x as the ML vector. Eq. (2) was used to determine the COP_y in the AP direction. Eq. (3) was used to determine COP_r in the resultant plane.

$$(1)\ \sum_{i=1}^{n}(COP_{x(i+1)} - COP_{x(i)})$$

$$(2)\ \sum_{i=1}^{n}(COP_{y(i+1)} - COP_{y(i)})$$

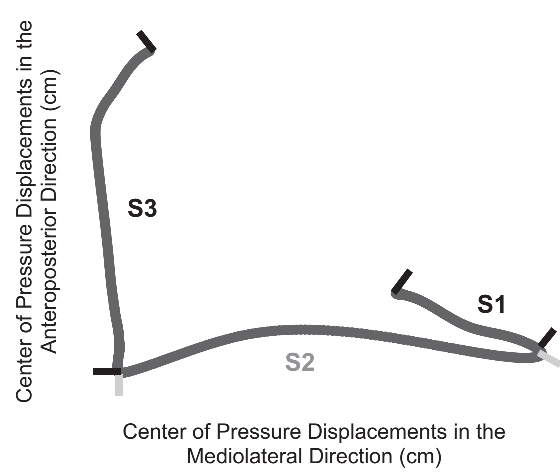

Fig. 1. Gait initiation profile of a representative subject.