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Original research study

# Investigating the anticipatory postural adjustment phase of gait initiation in different directions in chronic ankle instability patients

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ABSTRACT

*Objective:* The main objective of the present study was to analyze how supra spinal motor control mechanisms are altered in different directions during anticipatory postural phase of gait initiation in chronic ankle instability patients. It seems that supra spinal pathways modulate anticipatory postural adjustment phase of gait initiation. Yet, there is a dearth of research on the effect of chronic ankle instability on the anticipatory postural adjustment phase of gait initiation in different directions.
*Method:* A total of 20 chronic ankle instability participants and 20 healthy individuals initiated gait on a force plate in forward, 30° lateral, and 30° medial directions.
*Results:* According to the results of the present study, the peak lateral center of pressure shift decreased in forward direction compared to that in other directions in both groups. Also, it was found that the peak lateral center of pressure shift and the vertical center of mass velocity decreased significantly in chronic ankle instability patients, as compared with those of the healthy individuals.
*Conclusion:* According to the results of the present study, it seems that chronic ankle instability patients modulate the anticipatory postural adjustment phase of gait initiation, compared with healthy control group, in order to maintain postural stability. These changes were observed in different directions, too.


## 1. Introduction

Lateral ankle sprain is the most common injury among athletes (Hopkins et al., 2012; Steib et al., 2013) and 30%–75% of patients report repeated injury (Hopkins et al., 2012; Wikstrom et al., 2010; Munn et al., 2010) and experience symptoms including pain, weakness, and giving way after the initial injury (Konradsen et al., 2002; Delahunt, 2007; Brown et al., 2008; Pope et al., 2011). Chronic Ankle Instability (CAI) can cause osteoarthritis (Valderrabano et al., 2006); it can also affect athletes' life style in drastic ways. Similar to other chronic injuries, CAI is a complex injury which causes considerable decrease in the quality of life (Kim et al., 2012). Two main types of factors, including mechanical (such as joint laxity) and functional (such as sensorimotor deficit) factors, explain residual symptoms (Hopkins et al., 2012) in CAI patients (Hopkins et al., 2012; Hass et al., 2010; Gutierrez et al., 2009). However, few studies have primarily focused on investigating the issue of alternation in supra spinal motor control.

Anticipatory Postural Adjustment (APA) is a part of gait initiation, which plays a crucial role in facilitating forward body movement (Hiraoka et al., 2014). The APA, or preparatory phase of gait initiation, is constrained by the secondary motor area. During the preparatory phase, the APA is expressed as a backward and lateral shift of the Center of Pressure (COP) moves toward, first, the swing leg side, promoting the Center of Mass (COM) acceleration forward and, then, toward the stance leg side (Hass et al., 2010). Also, the COM falls and, finally, the swing limb unloads during the swing phase of gait initiation (Chastan et al., 2010). According to the previous studies, the APA phase of gait initiation is seriously impaired in older adults and patients with Parkinson's disease

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(Halliday et al., 1998; Uemura et al., 2012); the main reason for this is claimed to be alteration of the supra spinal aspects of motor control (Hass et al., 2010). Thus, it seems that gait initiation is a functional task to assess supra spinal motor control mechanisms.

On the other hand, quick redirecting is believed to be one of the most prominent causes of CAI (Wikstrom et al., 2010). Most of the studies have examined gait initiation in a forward direction. It seems that velocity and direction of gait can be determined before heel off during preparatory phase of gait initiation (Corbeil and Anaka, 2011). Thus, it was assumed that insufficient APAs transpired when CAI patients initiated gait in 30° medial direction (swing limb diagonally going over the body). Thus, the main objective of the present study was to assess the APA phase of gait initiation in different directions in CAI patients as compared with that of the healthy participants. We examined the displacement and velocity of COP and vertical COM velocity during the APA phase of gait initiation in different directions.

## 2. Method and materials

### 2.1. Participants

A total of 20 CAI patients, aged 21.4 ± 1.3 years, with the average height of 164.5 ± 6.2 cm and weight of 61.8 ± 9.57 kg, as well as 20 healthy individuals, aged between 21.7 ± 1.5 years, with the average height of 166.5 ± 5.5 cm and weight of 64.2 ± 8.6 kg, participated in the present study. Sample size was calculated based on the pilot study, with10 participants in each group, considering Type one error ($\alpha = 0.005$) and Type two error ($\beta = 0.2$) (power of 80%). All the participants signed the consent form provided by the Ethical Committee of Shahid Behesti University of Medical Sciences, Tehran. Participants were selected following convenience non-random sampling method. Members of the experimental (CAI patients) and control (healthy individuals) groups were university students, majoring in Physical Education and Sports Sciences, who were non-professional athletes doing aerobic exercises at least three sessions per week for 90 min (Wikstrom and Hass, 2012). To enter the study, CAI patients were to acquire a score <90% in daily living activities and <80% in sport activities, based on the Iranian Foot and Ankle Ability Measure questionnaire (Mazaheri et al., 2010). CAI patients with right injured limb were included in the present study. The inclusion criteria were: first ankle sprain at least one year prior to the test, a minimum of one day break from activities after the first ankle sprain, recurrent sprain at least three months prior to the test, and a minimum of two episodes of giving way within the six months prior to the test (Hass et al., 2010; Gribble et al., 2014). CAI is characterized as repeated ankle sprain and/or episodes of 'giving way' with or without the ligamentous laxity; thus, no clinical test or diagnostic imagining was implemented to select the participants (Wikstrom and Hass, 2012). Also, exclusion criteria included neurological disorders, chronic lower extremity disorders, acute head injury, and lower extremity injuries within the three months prior to the test (Hass et al., 2010; Gribble et al., 2014).

### 2.2. Procedures

Kinetic data was collected on a force plate at 1000 Hz (Bertec Corporation, Columbus, and U.S.A). The participants performed gait in three directions. Directions of gait initiation were selected randomly using random number generator. Participants started the test by walking toward the target, following the signed directions located four meters away from the force plate. They were asked to stand bare foot on a force plate in upright posture. During the first trial, positions of the feet were self-selected and, then, marked for other trials. Gait was initiated immediately after hearing acoustic signal with maximum velocity in three directions of forward (0°), lateral (+30°), and medial (−30°) and the gait directions were marked on the force plate. All the participants initiated gait 10 times, 5 times using the right limb and 5 times using the left limb. A rest period of 5 min was given between each task for each direction. All participants were dominant side injured limb (right side); therefore, the dominant limb of the control group was used for analysis and the non-dominant side uninjured limb was compared with non-dominant side of the control group.

### 2.3. Data processing

A customized program (Math Works Inc., R2013a) was used for data processing in MATLAB. The COP is automatically calculated by the software of the force plate. The software uses the following formula to calculate the COP displacement:

$$COP\ x = \frac{-My + Fx \times Z0}{Fz} + X0$$

$$COP\ y = \frac{Mx + Fy \times Z0}{Fz} + y0$$

where $M_{x, y}$ and $F_{x, y}$ are the moments and reaction forces in the medio-lateral, antero-posterior, and vertical directions, and x0, y0, and z0 are the offsets from the geometric center of the force plate (Lafond et al., 2004). The furthest lateral and posterior shift of COP (Mackinnon et al., 2007) and postero-lateral velocity of COP (as rate of reaching to furthest shift) were calculated using the customized program.

The COM parameters were calculated using the force data, acceleration of COM in the three directions were calculated using the Newton's second law (Force = mass x acceleration), and vertical velocity of COM was calculated by integrating vertical acceleration of COM extracted from $F_Z$ (Chastan et al., 2010). Moreover, the onset of the APA phase (t0) and the end of APA phase, referred to as Heel off time, were identified on the COP trace: t0 is the antero-posterior force which exceeded three Standard Deviations (SD) from the baseline found on the first 200 ms of each trial, when the participant stood motionless on a force plate, and Heel off time is integrating the vertical ground reaction force (Fz) after weight correction, referred to as vertical impulse (Caderby et al., 2013b).

### 2.4. Statistical analysis

The mean and SD of dependent variables were calculated for each individual direction. Normal distribution of the data was checked using Kolmogorov-Smirnov test. Multifactorial repeated measure ANOVA, group × direction × limb, was used to analyze all the variables. Within-subject factors included the three directions and the limb (right or left), and between-subject factor included the type of the group (healthy and CAI). Bonferonni Post hock test was conducted for further analysis of the collected data. *P*-values < 0.05 were considered to be significant.

## 3. Results and findings

The results revealed normal distribution of data ($P > 0.05$). According to the results of the independent *t*-test, no significant differences were observed between participants in terms of age, weight, and height ($P > 0.05$). Also, the results of the antero-posterior COM velocity showed no significant difference in the velocity of gait initiation between CAI and healthy group ($P = 0.258$).

According to the findings of the present study, there was a

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