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Individuals with chronic ankle instability compensate for their ankle deficits using proximal musculature to maintain reduced postural sway while kicking a ball

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A B S T R A C T

The aim of this study was to investigate anticipatory (APA), simultaneous (SPA) and compensatory (CPA) postural adjustments in individuals with and without chronic ankle instability (CAI) as they kicked a ball while standing in a single-leg stance on a stable and unstable surface. Electromyographic activity (EMG) of postural muscles and center of pressure (COP) displacements were calculated and their magnitudes analyzed during the postural adjustment intervals. Additionally, the COP area of sway was calculated over the duration of the whole task. The activities of postural muscles were also studied using principal component analysis (PCA) to identify between-group differences in patterns of muscle activation. The individuals with CAI showed reduced magnitude of EMG at the muscles around the ankle while around the hip the activity was increased. These were associated with a reduction in balance sway across the entire task, as compared with the control group. The PCA revealed that CAI participants assemble different sets of muscle activation to compensate for their ankle instability, primarily activating hip/spine muscles. These results set up potential investigations to examine whether balance control interventions enhance these adaptations or revert them to a normal pattern as well as if any of these changes proactively address recurrent ankle sprain conditions.

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1. Introduction

Chronic ankle instability (CAI) is characterized by recurrent sprains and the feeling of an ankle "giving way", resulting from a lateral ankle sprain (Freeman, 1965). CAI may cause deficits in postural control (Fu & Hui-Chan, 2005; Tropp, Ekstrand, & Gillquist, 1984), which is usually documented by visual inspection (Freeman, Dean, & Hanham, 1965) or by increased displacement of the body center of pressure (COP) when individuals balance themselves quietly in a single-leg stance (Knapp, Lee, Chinn, Saliba, & Hertel, 2011; Loudon, Santos, Franks, & Liu, 2008; Mitchell, Dyson, Hale, & Abraham, 2008; Ross, Guskiewicz, Gross, & Yu, 2009; Tropp, Odenrick, & Gillquist, 1985). Thus, balance training has been considered an important part in the rehabilitation and prevention of recurrent sprains in individuals with CAI (Bernier & Perrin, 1998; Eils & Rosenbaum, 2001; Rozzi, Lephart, Sterner, & Kuligowski, 1999; Tropp, 1986).

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Literature suggests physical therapists or athletic trainers usually perform balance training by using diversified external postural perturbations including, but not limited to, physically perturbing the individuals via a pull or push, or requesting them to throw, catch or kick a ball while standing on stable or unstable surfaces (Kidgell, Horvath, Jackson, & Seymour, 2007; Kolt & Snyder-Mackler, 2003). Although some of these training modalities have shown positive outcomes on static balance control and ankle joint stability, others displayed unsuccessful results (see Loudon et al., 2008; McKeon & Hertel, 2008 for review). Controversial findings may be due to limited understanding of how individuals with CAI react to these disturbances.

Different from balancing quietly on single leg, when individuals with CAI received postural perturbations (kicking a ball) in single-leg stance, they displayed a remarkable decrease in COP excursion (Dos Santos, Gorges, & Rios, 2014). The authors suggested that this decreased balance sway could be caused by the need for further stabilization of the ankle, via neuromuscular mechanisms, in more unstable postures to prevent recurrent sprain. However, there were no electromyographic (EMG) recordings of postural muscles used in this study. In addition, studies using drop/jump-landing tasks have shown that the EMG of the muscles around the ankle in individuals with CAI are decreased (Delahunt, Monaghan, & Caulfield, 2006; Suda & Sacco, 2011); hence, increasing ankle stiffness might be a difficult task for these individuals. Alternatively, they might use some type of compensatory mechanism during tasks involving these balance perturbation trainings, such as increasing the activity of the muscles in proximal joints.

Balance perturbation trainings for subjects with CAI usually aim to enhance joint proprioception and neuromuscular control around the impaired ankle. However, the maintenance of vertical posture during body disturbances relies not only on this site of proprioceptors and muscles, but also on those from other anatomical origins like the knee, hip and spine (Mohapatra, Kukkar, & Aruin, 2014; Santos & Aruin, 2009). For example, external oblique and gluteus medius muscles are highly required during postural perturbations in single-leg stance (Santos & Aruin, 2009). Moreover, balance perturbations in double-leg stance on unstable surfaces, such as a narrow base platform or foam, have shown to target more proximal than distal muscles to control balance (Horak & Nashner, 1986b; Kiers, Brumagne, van Dieen, van der Wees, & Vanhees, 2012). On the contrary, standing in single-leg stance seems to increase in general (distally and proximally) the activity of the muscles in comparison with standing in double-stance (Santos & Aruin, 2009). Thus, although perturbation training with individuals with CAI commonly use these training strategies, it is still unknown the extent these conditions affect the ankle joint muscles and others around the proximal joints.

While dealing with balance perturbations, anticipatory, simultaneous and compensatory postural adjustments (APA, SPA and CPA) (Nashner & McCollum, 1985) are the main types of postural strategies used to preserve the body equilibrium (Belen'kiĭ, Gurfinkel', & Pal'tsev, 1967; Fourcade, Hansen, LeBozec, & Bouisset, 2014; Friedli, Hallett, & Simon, 1984; Nashner & Cordo, 1981). APAs are associated with the synergic activation of postural muscles and discrete body movements just before a postural disturbance occurs. Their purpose is to minimize the adverse effects of the perturbation on postural balance (Bouisset & Zattara, 1987; Massion, 1992; Santos, Kanekar, & Aruin, 2010a). Anticipatory adjustments are triggered when the body perturbation is predicted and are controlled by a feed-forward mechanism (Aruin & Latash, 1995; Bouisset & Zattara, 1987; Massion, 1992; Zattara & Bouisset, 1988). This mechanism also seems to controls SPAs (at least at the beginning), which are responsible to minimize the postural disturbances (counter-perturbation) during the course of self-generated movement as well as to help (propulsion) in the voluntary movement of the limb (Fourcade et al., 2014). Otherwise, CPAs deal with the perturbation itself and entail the coupling of postural muscle activation and movement strategies to restore postural balance after the body disturbance has occurred (Alexandrov, Frolov, Horak, Carlson-Kuhta, & Park, 2005; Henry, Fung, & Horak, 1998; Horak & Nashner, 1986a; Macpherson, Horak, Dunbar, & Dow, 1989; Maki & McIlroy, 1996; Nashner & Cordo, 1981; Park, Horak, & Kuo, 2004). CPAs are generated either by predictable or unpredictable perturbations and are driven by feedback mechanisms. These adjustments are usually observed via EMG recordings, as well as by COP displacement and joint movement (Santos, Kanekar, & Aruin, 2010b; Santos et al., 2010a). Investigating these postural strategies in individuals with CAI will reveal how they control their body equilibrium during balance perturbation tasks.

Therefore, the current experiment was designed to analyze the influence of a balance perturbation task on APAs, SPAs and CPAs in individuals with CAI in stable and unstable surfaces. Subjects with CAI and controls were exposed to similar perturbations of kicking a moving ball while standing in single-leg stance on stable and unstable surfaces. Individuals with CAI usually show decreased EMG at the muscles around the ankle (distal) and decreased COP excursion during functional tasks. We therefore hypothesized that: individuals with CAI will present decreased postural adjustments (APA, SPAs, and CPAs) at the distal muscles, which will be compensated by muscles around the hip (proximal) to maintain the observing reduced balance sway. The unstable surfaces may increase the activity of the proximal muscles and the COP displacement as compared to the stable surface. A better understanding of postural adjustments during this task will be important to support and improve interventions aiming to enhance balance control in individuals with CAI.

2. Methods

2.1. Participants

A total of 42 young adults were recruited from the local community (University and surroundings) and sorted into two groups: 21 individuals with CAI (CAI group – 13 women and 8 men; mean age 25 years, range 20–31) and 21 healthy