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ORIGINAL RESEARCH

Both anticipatory and compensatory postural adjustments are adapted while catching a ball in unstable standing posture

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Summary The main objective of this study was to analyze the role of balance exercises on anticipatory (APA) and compensatory (CPA) postural adjustments in different conditions of postural stability. Sixteen subjects were required to catch a ball while standing on rigid floor, trampoline and foam cushion surfaces. Electromyographic activities (EMG) of postural muscles were analyzed during time windows typical for APAs and CPAs. Overall there were a reciprocal activation of the muscles around the ankle and co-activations between ventral and dorsal muscles of the thigh and trunk during the catching a ball task. Compared to the rigid floor, the tibialis anterior activation was greater during the trampoline condition (CPA: $p = 0.006$) and the soleus muscle inhibition was higher during foam cushion condition (APA: $p = 0.001$; CPA: $p = 0.007$). Thigh and trunk muscle activities were similar across the conditions. These results advance the knowledge in postural control during body perturbations standing on unstable surfaces.
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Introduction

When posture is disturbed, humans use two main types of postural adjustment to maintain body balance: anticipatory postural adjustment (APA) (Belenkii et al., 1967) and compensatory postural adjustment (CPA) (Nashner and McCollum, 1985). APAs are associated with the synergic activation of postural muscles and discrete body movements that occurs just before postural perturbation (Krishnan et al., 2012; Santos et al., 2010b). Their purpose is to minimize the adverse effects of the disturbance on postural balance (Bouisset and Zattara, 1987; Santos et al., 2010b). APAs are triggered when the body perturbation is predicted and are controlled by feed forward mechanisms (Aruin et al., 2015; Aruin and Latash, 1995; Bouisset and Zattara, 1987; Massion, 1992). On the other hand, CPAs deal with the perturbation that has already occurred, and entail the coupling of postural muscle activation and movement strategies to restore postural balance after the body disturbance (Alexandrov et al., 2005; Henry et al., 1998; Horak and Nashner, 1986; Macpherson et al., 1989; Maki and McIlroy, 1996; Nashner and Cordo, 1981; Park et al., 2004). CPAs are generated either by predictable or unpredictable perturbations and are driven by feedback mechanisms (Kanekar and Aruin, 2014; Nashner and Cordo, 1981).

Studies have shown that healthy young individuals preselect their strategies to generate postural adjustments to counteract postural perturbations either induced by internal (created by self-initiated movement) (Aruin and Latash, 1995) or external disturbances (produced by forces that act outside the person) (Rogers et al., 2003; Santos et al., 2010a). Therefore, the central nervous system (CNS) is able to modify motor responses based upon the characteristics of the perturbation (Shiratori and Latash, 2001), including its magnitude, type of task (Shiratori and Latash, 2000), and postural orientation (Aruin and Latash, 1995; Santos and Aruin, 2008).

Anecdotally and based upon the literature, physical therapists and athletic trainers usually perform balance exercises using postural perturbations such as standing on one leg on unstable surfaces and/or throwing, catching or kicking a ball (Kisner and Colby, 2007) with the subjects positioned on unstable surfaces like foam cushions (Heitkamp et al., 2001) and mini trampolines (Aragão et al., 2011; Heitkamp et al., 2001). These exercises aim to make the tasks more difficult by reducing the reliability of somatosensory information (Fitzpatrick et al., 1994; Lord et al., 1991; Patel et al., 2011; Vuillerme and Pinsault, 2007) increasing postural sway (Lord et al., 1991). In addition, balancing on unstable surfaces may increase the magnitude of activation in distal muscles and joint torques around the ankle (Almeida et al., 2006; Ivanenko et al., 1997).

While results of previous cited studies have important implications in the rehabilitation field, data on central nervous system modulation of APAs followed by CPAs as a result of external perturbations in conditions of postural instability are scarce. In addition, studies that systematically investigate APAs or CPAs, did not reproduce rehabilitation protocols, such those that use perturbations as throwing or catching a ball (Cordasco et al., 1996; Duran et al., 2001) standing on stable and unstable surfaces (Kisner and Colby, 2007).

Therefore, the main objective of this study was to analyze the role of balance exercises on APAs and CPAs in different conditions of postural stability. Based on aforementioned studies our hypothesis is that both anticipatory and compensatory activity will increase in conditions of postural instability, especially for the distal muscles located closer to the unstable surfaces. A better understanding of APAs and CPAs during these tasks will be important to support and improve therapeutic interventions based on balance exercises.

Methods

Participants

Sixteen young adults (10 women, 6 men, age range: 19—38 years; body mass range: 45—75 kg; height range: 154—182 cm) were recruited from the Center of Health Sciences and Sports of the Santa Catarina State University to participate in the study. All the participants were students or faculty members engaged in recreational activities, most of them in soccer and running. Anyone with a history of orthopedic problems, neurological disorders, or any other condition that might interfere with task performance was excluded. All subjects were informed about the objectives and procedures to be completed in the research and signed a written informed consent approved by the local Ethics Committee.

Materials

The EMG of the muscles was evaluated via electromyography (EMG System of Brazil ®, model 811C, São José dos Pinhais, SP, Brazil) with an analog output, gain rate of 2000, band pass filter from 23 to 500 Hz, Common Mode Rejection Ratio (CMRR) greater than 80 dB, and differential amplifier. Timing of the perturbation was recorded by an accelerometer (EMG System do Brasil®, model ACL13000/03, São José dos Pinhais, SP, Brazil) attached to a medicine ball (Medicine Ball, VERTEX 1 kg) used in the experiment. All signals were sent to a computer through a digital/analog acquisition system (model PCI 6259, National Instruments, USA) with a frequency of 1000 Hz and resolution of 16 bits, acquired in a LabView environment (SignalExpress ® 2010, Version 4.0. 0 for Windows ®, National Instruments, USA).

Procedures

Disposable surface electrodes (3M ®, 223BRQ, Sumaré, SP, Brazil) were placed on the skin of individuals with an interelectrode distance of 20 mm, after shaving and cleansing with 70% alcohol. Electrodes were placed on the dominant side of each participant on the following postural muscles: soleus (SOL), tibialis anterior (TA), biceps femoris (BF), rectus femoris (RF), rectus abdominis (RA), and erector spinae (ES). The triceps brachii (TB) muscle also on the dominant side was recorded and denoted as a focal muscle, as it was the primary effector of the experimental activity