Gait & Posture 41 (2015) 499–503

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Visual feedback of the centre of gravity to optimize standing balance

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ARTICLE INFO

Article history:
Received 28 July 2014
Received in revised form 28 October 2014
Accepted 1 December 2014

Keywords:
Balance
Posture
Centre of pressure
Centre of gravity
Motor learning

ABSTRACT

Force platform biofeedback training, whereby concurrent visual feedback of the centre of pressure (COP) is provided, has previously been used for balance training. Since the goal of balance is to maintain control of the centre of gravity (COG), specific feedback of the COG may be more likely than COP feedback to improve overall balance control. The purpose of this study was to compare the effect of concurrent visual feedback of the COP versus COG on postural control during a novel quiet standing task. Thirty-two young healthy adults (20–35 years old) were recruited. Participants were randomly assigned to receive concurrent visual feedback of either the COP or COG while standing on a foam pad. Training occurred over one session (20–30-second trials). Retention and transfer testing (i.e. without concurrent visual feedback) occurred after ∼24 h. Variability of the COG decreased, variability of COP–COG increased, and sample entropy increased with concurrent visual feedback. With practice, variability of COP, COG and COP–COG decreased whereas sample entropy increased. The decrease in variability of COP–COG was greater for those who received COG feedback than those who received COP feedback. Training effects on COP, COG and COP–COG variability were not retained after 24 h and removal of visual feedback. However, on retention and transfer testing, sample entropy was significantly higher than on baseline testing, indicating more 'automatic' postural control. These results suggest that concurrent visual feedback of neither the COP nor COG is superior for improving quiet standing balance control.

1. Introduction

During quiet, unperturbed standing, small ankle and hip adjustments act to maintain balance in the face of continuous postural sway. This quiet standing balance control can be considered a learned feature of the central nervous system [1] that, similar to other learned motor skills, can improve with practice. Studies involving repeated testing of quiet standing balance have observed either short-term (within session [2,3]) or long-term (across days [4,5]) reductions in postural sway with repetition of a quiet standing task. Although acquisition of a novel balance skill may be dependent on initial balance capacity [6], this improvement can occur for a relatively simple, presumably well-learned, task (i.e. standing still) among healthy young individuals and without any instruction or experimental strategy to promote learning.

While balance control may not be considered a novel motor skill beyond childhood, the same principles of learning that apply to learning novel motor skills can be applied to continually refine balance control across the life span, or re-learn balance control following neurological injury [1]. Augmented feedback is frequently used to aid learning of novel motor skills by providing learners with information about performance of the skill not appreciated by their own sensory feedback [7–9]. One popular option for balance training is to have participants stand on a force platform while providing continuous visual feedback of the centre of pressure (COP) and instructing participants to minimize movement of the COP in quiet standing [10–13]. This type of training appears to be effective for reducing postural sway and improving balance control among older adults [14].

Alternatively, force platform biofeedback could provide individuals with feedback regarding the estimated location of the centre of gravity (COG). Balance control focuses on the outcome of maintaining stability, with less emphasis on how that stability was maintained. The process by which balance control is learned may reflect this distinction. The outstanding question, with respect to

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http://dx.doi.org/10.1016/j.gaitpost.2014.12.003
0966-6362/

balance control, is what feature of balance responses individuals identify in order to learn from experience. In quiet standing when only the feet are in contact with the ground, the goal is to maintain control of the COG, which is accomplished by ankle and hip movements that alter the location of the COP [15]. Therefore, the COP acts as a controlling variable of the true outcome of interest: the COG, which is the controlled variable. Previous research has found that visual feedback of the COP can indeed reduce variability of movement of both the COP and the COG [16]. However, given that the COP is simply a controlling variable of the COG, it remains to be determined whether providing direct feedback of the COG, a more accurate indicator of performance, might result in different motor learning strategies that lead to overall improved balance control.

The purpose of this study was to determine the effect of providing feedback the COG versus feedback of the COP on control of a simple quiet standing balance task. It was hypothesized that healthy young adults who receive concurrent visual feedback of their COG during a single training session on an unstable surface will demonstrate a greater ability to minimize their COP–COG compared to a group which receives feedback of their COP. A secondary objective was to explore changes in attentional investment in postural control over the course of the training period.

2. Methods

2.1. Participants

Thirty-two healthy young adults (16 men, 26 ± 4 years old) participated in this study (Table 1). The study was reviewed and approved by the Research Ethics Board at the University Health Network and all participants provided informed consent prior to participating. None of the participants had any neurologic or musculoskeletal disorders that affected balance control. To ensure that participants could adequately view the visual feedback, participants were excluded if Snellen visual acuity was equal to or worse than 20/80 in either eye, indicating low vision; participants wore their usual glasses or contact lenses, if needed, for all testing. Participants were sub-stratified by sex and randomly allocated into one of two groups, ensuring an equal number of men and women in each group. The COP_f group received visual feedback of their COP during the feedback trials whereas the COG_f group received visual feedback of their COG during the feedback trials.

2.2. Protocol

Participants attended the laboratory on two consecutive days to complete a series of standing balance tasks. Participants stood barefoot or wearing socks only on a 40 cm × 50 cm foam pad (Balance-pad, Airex AG, Sins, Switzerland). The foam pad was used to provide greater challenge to balance control than standing on a firm surface within this healthy unimpaired group and, thus, to increase the likelihood that training effects would be observed. Feet were placed in a standardized foot position (0.17 m between heel centres, with an angle of 14° between the long axes of the feet [17]), which was marked on the foam using tape. The foam was fixed on top of a single 50 cm × 50 cm force plate (Advanced Medical Technology Inc., Watertown, MA, USA). A 21 in. computer monitor was placed approximately 60 cm in front of the participant at eye level (Fig. 1).

The trial block order is presented in Fig. 2. During the first session, participants completed five baseline (B) trials, in which they were instructed to stand as still as possible while maintaining eye contact with a fixed target that appeared on the screen in front of them. All trials were 35 s in duration. The average COP and COG and the standard deviations of those measures of each participant were recorded in the baseline trials and were used to tailor the feedback provided to each participant. During the subsequent acquisition 20 trials in the first session (A1–A4), participants were provided real-time visual feedback at 200 Hz of either their antero-posterior COP or COG (estimated from Eqs. (1)–(4) [18]), dependent on their group allocation. COP or COG

Table 1
Participant information. Values are expressed as mean ± standard deviation unless otherwise indicated.

	COP_f group	COG_f group
Sex (#M/#F)	8/8	8/8
Age (years)	25 ± 3	27 ± 4
Height (m)	1.70 ± 0.11	1.72 ± 0.08
Weight (kg)	66 ± 11	69 ± 11

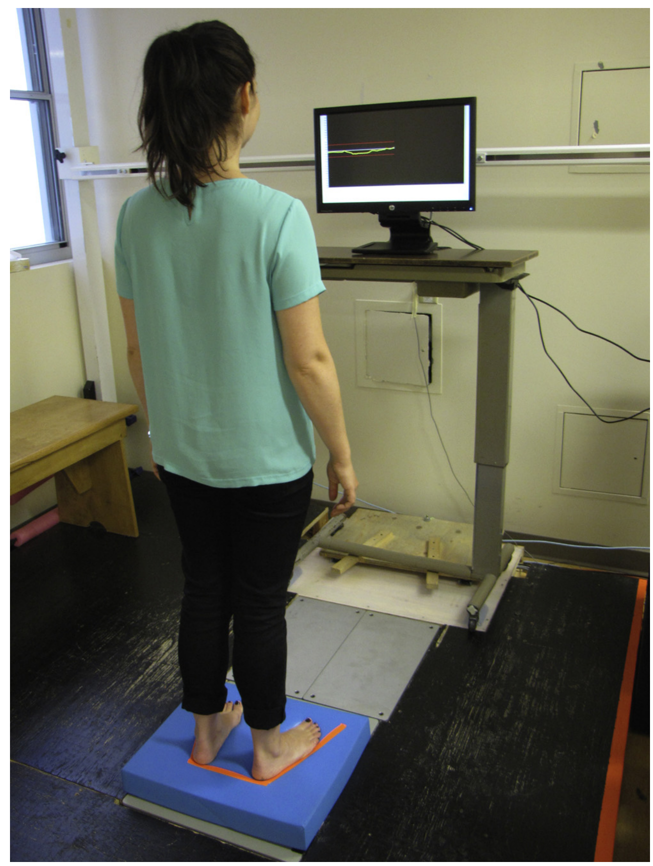

Fig. 1. Participant setup. Participants stood on a foam pad in a standardized foot position (marked with orange tape on the pad) on top of a single force plate. During acquisition and retention trial blocks, participants received real-time visual feedback of either their COP or COG, dependent on group allocation.

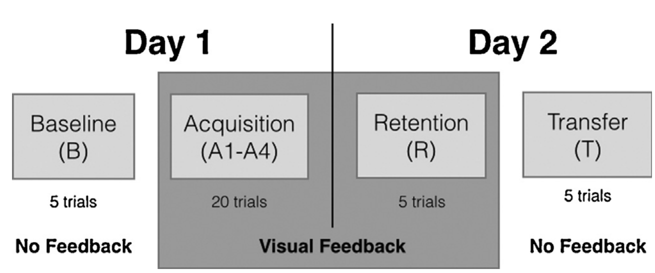

Fig. 2. Protocol schematic. Participants attended the lab on two separate days, approximately 24 h apart. Dark grey shading denotes that trials included visual feedback.