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Benefits of multi-session balance and gait training with multi-modal biofeedback in healthy older adults

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ABSTRACT

Real-time balance-relevant biofeedback from a wearable sensor can improve balance in many patient populations, however, it is unknown if balance training with biofeedback has lasting benefits for healthy older adults once training is completed and biofeedback removed. This study was designed to determine if multi-session balance training with and without biofeedback leads to changes in balance performance in healthy older adults; and if changes persist after training. 36 participants (age 60–88) were randomly divided into two groups. Both groups trained on seven stance and gait tasks for 2 consecutive weeks (3×/week) while trunk angular sway and task duration were monitored. One group received real-time multi-modal biofeedback of trunk sway and a control group trained without biofeedback. Training effects were assessed at the last training session, with biofeedback available to the feedback group. Post-training effects (without biofeedback) were assessed immediately after, 1-week, and 1-month post-training. Both groups demonstrated training effects; participants swayed less when standing on foam with eyes closed (EC), maintained tandem-stance EC longer, and completed 8 tandem-steps EC faster and with less sway at the last training session. Changes in sway and duration, indicative of faster walking, were also observed after training for other gait tasks. While changes in walking speed persisted post-training, few other post-training effects were observed. These data suggest there is little added benefit to balance training with biofeedback, beyond training without, in healthy older adults. However, transient use of wearable balance biofeedback systems as balance aides remains beneficial for challenging balance situations and some clinical populations.

1. Introduction

In comparison to young adults, healthy older adults sway more [1] and have an increased risk of falls [2]. Age-related changes to balance performance in otherwise healthy individuals may be related to natural deterioration of sensory function with age [3–6]. One way to counteract these increases in sway is to provide additional balance-related sensory biofeedback [7–9].

Balance-biofeedback systems record body sway with either a fixed (e.g. motion capture) or wearable sensor (e.g. gyroscopes or accelerometers) interfaced with a feedback device to provide sensory feedback either in real-time (during performance) or post-performance. Feedback can be unimodal (e.g. vibrotactile [8,11], auditory [12,13] or visual [8,14]) or multi-modal [7,15,16]; and can be incorporated into a balance task (e.g. balance training or video game) or presented as non-task-specific feedback (e.g. as a prosthetic). Balance-biofeedback has been shown to decrease postural sway in a variety of stance and gait tasks in healthy individuals [7–9,23] and clinical populations [15–18] during, or immediately after, balance-biofeedback training. Most studies involving body-worn sensor systems have used short-term or single session training and were not designed to investigate post-training effects. To date, only two multi-session studies have demonstrated lasting balance improvements in people who trained with balance-relevant vibrotactile biofeedback from a

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wearable sensor [10,11]. However, these studies only examined people with chronic dizziness, and improvements were referenced to people who trained with non-balance related, pseudo-random vibrotactile signals that may be distracting. Since multi-session balance [19,20] or exercise [21,22] training without biofeedback and video game-based balance training [23] lead to improved balance performance in healthy older adults, it is important to determine if multi-session balance training with real-time biofeedback from a wearable sensor offers benefits beyond training alone in an otherwise healthy population. To our knowledge, no randomized control trials have investigated multi-session training and post-training effects of balance-relevant biofeedback from a wearable biofeedback device in healthy older adults.

The aims of this study were (1) to determine if multi-session training, with or without real-time biofeedback, led to changes in trunk sway and task duration in healthy older adults during balance and gait tasks and (2) to determine if changes in performance persisted up to 1-month post-training. Based on the results of a single-session biofeedback training study in young and older adults [7], we hypothesized trunk sway angle would be significantly reduced in both the pitch and roll planes and task duration would be improved (i.e. longer for stance, shorter for gait tasks) post-training, with greater changes after training with biofeedback. We also hypothesized post-training effects would persist up to 1-month post-training, with longer and greater retention from training with biofeedback.

2. Methods

Forty-five healthy community-dwelling older adult (≥60 years) participants were recruited with advertisements placed in the community and by word of mouth. Forty-two participants met the eligibility requirements and were randomly assigned to either the biofeedback (FB) or control (CTRL) group; participants were compensated CAD$40 for participating. No participants reported balance deficits, used support devices to walk or stand, had knee or hip replacements, or had, or were at a high risk of having osteoporosis. Of these participants, 36 were included in the final analysis (18 FB: 11 female, age 69 ± 7; 18 CTRL: 14 female, age 70 ± 6; age range 60–88); 3 participants dropped out due to time commitments and 3 were excluded because of technical difficulties (Fig. 1A). Each individual provided written informed consent prior to participation. The University of British Columbia Clinical Research Ethics Board reviewed and approved all procedures. This study conforms to the Declaration of Helsinki.

Trunk sway was measured using a SwayStar^{TM} device (Balance Int. Innovations GmbH, Switzerland) fastened to the lower back

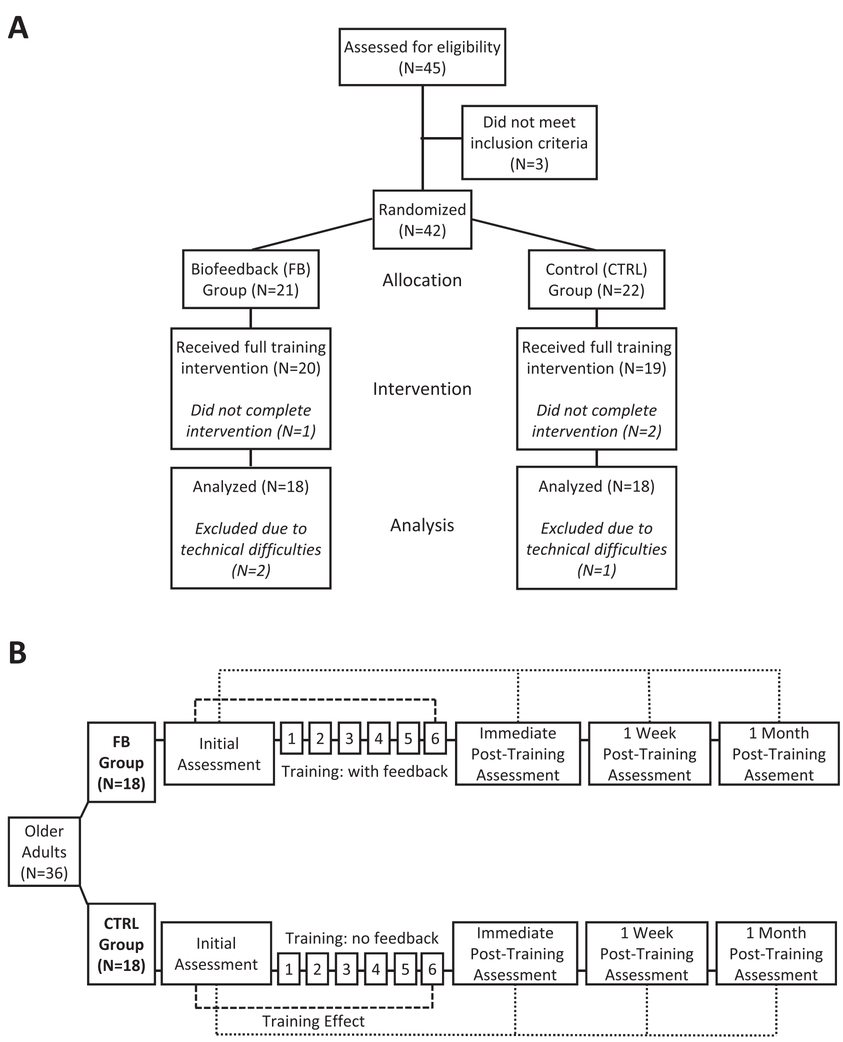

Fig. 1. Schematics of (A) participant stratification and (B) study protocol. Dashed and dotted lines indicate time points for statistical analysis of training and post-training effects, respectively.