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Trunk motion visual feedback during walking improves dynamic balance in older adults: Assessor blinded randomized controlled trial

Eric Anson[a,*], Lei Ma[b,e], Tippawan Meetam[c], Elizabeth Thompson[b,e], Roshita Rathore[b], Victoria Dean[d], John Jeka[b]

[a] Department of Otolaryngology Head & Neck Surgery, Johns Hopkins School of Medicine, Baltimore, MD, United States
[b] Department of Kinesiology, Temple University, Philadelphia, PA, United States
[c] Division of Physical Therapy Faculty of Health Science Srinakharinwirot University, Ongkharak Campus, Nakhonnayok, Thailand
[d] Physical Therapy Department, Thomas Jefferson University, Philadelphia, PA, United States
[e] Department of Physical Therapy, Temple University, Philadelphia, PA, United States

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ABSTRACT

Background: Virtual reality and augmented feedback have become more prevalent as training methods to improve balance. Few reports exist on the benefits of providing trunk motion visual feedback (VFB) during treadmill walking, and most of those reports only describe within session changes.

Research question: To determine whether trunk motion VFB treadmill walking would improve over-ground balance for older adults with self-reported balance problems.

Methods: 40 adults (75.8 years (SD 6.5)) with self-reported balance difficulties or a history of falling were randomized to a control or experimental group. Everyone walked on a treadmill at a comfortable speed 3×/week for 4 weeks in 2 min bouts separated by a seated rest. The control group was instructed to look at a stationary bulls-eye target while the experimental group also saw a moving cursor superimposed on the stationary bulls-eye that represented VFB of their walking trunk motion. The experimental group was instructed to keep the cursor in the center of the bulls-eye. Somatosensory (monofilaments and joint position testing) and vestibular function (canal specific clinical head impulses) was evaluated prior to intervention. Balance and mobility were tested before and after the intervention using Berg Balance Test, BESTest, mini-BESTest, and Six Minute Walk.

Results: There were no significant differences between groups before the intervention. The experimental group significantly improved on the BESTest ($p = 0.031$) and the mini-BEST ($p = 0.019$). The control group did not improve significantly on any measure. Individuals with more profound sensory impairments had a larger improvement on dynamic balance subtests of the BESTest.

Significance: Older adults with self-reported balance problems improve their dynamic balance after training using trunk motion VFB treadmill walking. Individuals with worse sensory function may benefit more from trunk motion VFB during walking than individuals with intact sensory function.

1. Introduction

Falls are the leading cause of fatal and nonfatal injuries in older adults [1,2]. Close to one third of the population over the age of 65 fall annually, with a half of those falls leading into injuries [2,3]. Aging is accompanied by an overall reduction in mobility and decrease in sensory integration which have been associated with falls [4–6]. Visual feedback/augmented reality for balance training has become more common method to reduce fall risk [7]. These technologies afford new avenues to enhance balance ability in a safe, controlled, and engaging environment [8].

Most visual feedback (VFB) balance interventions have focused on standing or weight-shifting tasks [9–16], however, falls primarily occur during locomotion [3,17,18]. While virtual/augmented reality (VR) training has recently been shifting to more dynamic activities like walking, the majority of the walking VFB training is based on foot or leg kinematics with an emphasis on normalizing the gait cycle [19–23]. Control of foot placement is important for controlling displacement of

Abbreviations: VR, virtual/augmented reality; ML, mediolateral; AP, anterior-posterior; VFB, visual feedback; mBEST, mini-BESTest; BBS, berg balance scale; TUG, timed up and go; ABC, activities-specific balance confidence; 6MWT, 6 min walk test

* Corresponding author at: 601 Elmwood Ave, Box 629, University of Rochester, Rochester, NY, 14642, United States.
E-mail address: eric_anson@urmc.rochester.edu (E. Anson).

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the whole body center of mass, but upright trunk orientation is degraded for individuals with balance problems [24,25]. Specifically, excessive forward trunk lean during walking has been associated with increased fall risk [26].

Training foot placement may contribute to enhanced control of center of mass translation [27], but may be insufficient to improve trunk on legs orientation as the legs and trunk respond differently and on different time scales to sensory perturbations [28,29]. VFB training involving trunk orientation and trunk translation would allow the individual to more flexibly solve the stability problem (trunk on legs, stepping, or both) by taking advantage of their many degrees of freedom [30]. Considering the benefits of improved trunk motion for balance [31], providing concurrent VFB of trunk motion during walking may be a beneficial training strategy to improve balance [32].

This study builds on responses to *concurrent* trunk motion VFB during treadmill walking [32,33] to investigate carry over and transfer to over-ground dynamic balance for older adults at risk of falling. The primary aim of this study was to determine whether training with trunk motion VFB for 4 weeks would result in improved balance for older adults with self-reported balance problems. We hypothesized that training with trunk motion VFB while walking on a treadmill will improve balance measured with clinical tests of dynamic balance.

2. Methods

2.1. Design overview

This study was a 2 arm, assessor blinded experimental design with random assignment to the control and experimental arms.

2.2. Setting and participants

40 older adults with self-reported balance difficulties or a history of falling completed this study (Clinical Trial # 366151-1, www.ClinicalTrials.gov). The average age of the control group was 75.8 years (SD 6.5, range 66–92 years) and 65% of them were female. The average age of the experimental group was 75.7 years (SD 5.3, range 68–87 years) and 80% were female. This study was approved by the Institutional Review boards at the University of Maryland and Temple University. All subjects provided written informed consent prior to participation. The experiment was performed at two locations: Temple University and Collington Episcopal Life Care Community. After providing informed consent and passing the Mini Mental Status Exam (scores > 23) subjects demonstrated they could safely and independently walk on a treadmill for at least 2 min at a self-selected speed. Subjects were excluded for not passing the Mini Mental Status Exam (n = 1) or not safely and independently walking on the treadmill for 2 min (n = 1). The assessors were blinded to group allocation until the study was completed. No attempt was made to blind the subjects, although they were not explicitly told whether they were in the control or VFB group.

2.3. Randomization and interventions

Individuals were randomized into either the experimental (n = 20) or control (n = 20) arms of the study. For each recruitment phase the study coordinator (LM) assigned participants a computer generated random number determining group allocation, see Fig. 1.

2.4. Trunk motion visual feedback

Subjects walked on a treadmill,[1] approximately 24 inches in front of a 27” TV[2] as shown in Fig. 2. The VFB device has been described in detail and is briefly presented here [32]. Each of the 10 rings of the bull's-eye was one inch wide and corresponded to one inch of physical space on the treadmill (translation) or 1° from vertical (orientation). Two webcams[3] tracked the 3-D position of three markers (at the navel, and each shoulder, see the inset of Fig. 2) attached to suspenders [32]. The subject's virtual motion (translation vs. orientation) was displayed in the form of a moving cursor on the TV screen. Translation was defined as the 2-dimensional (anterior-posterior [AP] and mediolateral [ML]) displacement of the lower marker on the suspenders, see inset Fig. 2. Orientation with respect to vertical was defined as the angular deviation of the trunk segment (defined by the lower marker and the midpoint of the two upper markers) from vertical [34]. Cursor motion was smoothed using a 5 point moving average filter and scaled to map subject motion to on screen cursor motion in a 1:1 manner.

2.5. Intervention procedures

The VFB training sessions lasted 30 min and were conducted 3 times per week for 4 weeks. Training sessions always consisted of the following: subjects were asked if they had fallen since their last session and donned a safety harness. Subjects were instructed to use the handrails only if they lost balance. Each session, the subject's “comfortable speed” was determined: the treadmill speed was increased until the subject said “too fast” and then decreased speed until the subject said “too slow.” The midpoint of “too fast” and “too slow” was their “comfortable speed” for that session [35,36]. Subjects were blinded to their walking speed. During the first training session, subjects in the experimental group were instructed on how to interact with both types of trunk motion VFB (translation and orientation). They were briefly trained and demonstrated the ability to keep the cursor “as close to the center of the bull's-eye as possible,” minimizing displacement or angular deviations. VFB sessions consisted of 2 min walks with VFB, followed by a seated rest (30, 60, or 120 s at the subject's request). That process was repeated for 30 min resulting in 8–12 walking bouts per session. The VFB (translation and orientation) order was randomized during each training session, each 2 min walking bout provided either translation *or* orientation VFB. The experimental group was informed as to the type of VFB prior to each 2 min bout.

The control group also attended the same training schedule. The procedures were the same except that they did not receive training in how to use the VFB, and they did not see or interact with the VFB. The bulls-eye was visible and the control group was instructed to look at the center of the bulls-eye while walking. Walking and seated rest timing was the same as for the experimental group.

2.6. Outcomes and follow-up

The standardized gait and balance assessments were administered by blinded assessors (EA, ET, RR) at Pre-test 1 (week 1), Pre-test 2 (week 4) and the Post-test (week 8). The experimental timeline is provided in Table 2. No further follow up was provided. The BESTest, mini-BESTest (mBEST), Berg Balance Scale (BBS), Timed Up and Go (TUG), Activities-specific Balance Confidence (ABC) scale, and 6 min walk test (6MWT) have excellent test-retest reliability (ICCs 0.84–0.99) and were used to characterize balance and walking ability [37–44]. The primary outcome measures were BESTest and mBEST scores, which may provide systems level mechanistic insight into clinical balance problems [42]. The BESTest is a physical performance test with 27 items distributed among six sub-systems of static and dynamic balance: 1) biomechanical constraints, 2) stability limits/verticality, 3) anticipatory postural adjustments, 4) postural responses, 5) sensory orientation, and 6) stability in gait [42]. The BESTest may allow for more

[1] Suppliers list:Cybex Trotter 900T, Cybex International, 10 Trotter Dr, Medway, MA.

[2] Suppliers list: ViewSonic VA2703, Viewsonic Corporation, 10 Pointe Dr, Brea, CA.

[3] Suppliers list: Logitech Orbit AF, Logitech Int., 7700 Gateway Blvd., Newark, CA.