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EXPLORING TRAINING METHODOLOGIES TOWARDS THE IMPROVEMENT OF ELDERLY BALANCE

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ABSTRACT

The purpose of this study was to investigate the effects of utilizing sensory (i.e., vision and touch), as well as static and dynamic base of support training on the balance of senior participants aged 60 – 80 years old. For each participant, there were several weeks of training, two sessions per week and assessments every two weeks. Training included walking and standing exercises on a hard surface, compliant and stiffer foam walking and standing balance training, and navigating obstacles. Within each session, to modify vision, all training included eyes-open and closed. Further, there were increases in training difficulty as the sessions progressed.

It was observed that training over several weeks resulted in increases in stability, as observed by the decreases in Balance Error Scoring System (BESS) assessment results. However, increases in balance confidence, as observed by the Activities-Specific Balance Confidence (ABC) scale were less certain in this healthy elderly (or senior) population. It is an interesting and positive finding that, in doing relatively simple, but targeted exercises and training, senior individuals can have moderate improvements in their balance and, perhaps ultimately, reduce their fall-risk.

INTRODUCTION

The number of seniors > 60 years old is set to double within the next couple of decades and, as a consequence, the frequency of falls is also predicted to increase. Societal changes, including the investigations of training methodologies and assistive devices to prevent falls, is greatly needed [1-4].

Approximately 1 in 4 Americans over 65 years old will experience falls. Further, 2.8 million elderly Americans are treated for fall-related injuries each year with $31 billion dollars in direct medical costs resulting from these injuries, annually [5]. Falls can lead to fractures, pain, and functional impairment. Aside from the physical harm and injury a fall may cause, the psychological fear of falling can cause a severe drop in (balance) confidence for everyday activities resulting in an overall decreased quality of life. For example, one may develop a fear of encountering daily-living scenarios wherein one's balance may be challenged (e.g., walking on an icy sidewalk), therefore, limiting their activity.

It is well known that inputs to the visual, somatosensory and vestibular systems are used for postural control. The visual system allows us to perceive our own motion and position relative to the world around us. From the somatosensory system, subcutaneous touch and pressure receptors (for example in one's feet) can be used to determine body position with respect to an external reference. Pressure receptors are stimulated in the feet when standing on a support surface. The vestibular system within the inner ear senses angular head velocity and linear head acceleration which contributes to one's equilibrium and spatial orientation. The systems above detect information from the environment and transmit it to the central nervous system (CNS) for subsequent processing. Lower levels of the CNS trigger an automatic postural response while the higher levels of the CNS develop internal representations of body motion in space via sensorimotor integration [6]. Depending on sensory information available, central mechanisms will adjust incoming sensory information so that reliance is placed on the available cues to maintain balance and posture.

Two important behavioral goals of the postural control system are postural orientation and postural equilibrium. Postural orientation is the relative positioning of body segments with respect to one another and is based on specific task and postural references. Postural equilibrium (balance) is the state in which the net forces acting on the body are balanced. One of the main goals of postural equilibrium is to control the position and velocity of the center of mass (COM) (i.e., the point at which the entire distributed mass of the body is balanced). Destabilizing influences, such as gravity, produce external forces on the body. In order to control the position of the COM and maintain equilibrium, internal (body) forces attempt to counteract destabilizing, external forces. In order to maintain postural orientation and postural equilibrium, a high-level postural strategy is formulated by the nervous system for one or more postural goals (e.g., trunk orientation, gaze fixation, or energy expenditure) [6].

An individual's base of support is the region bounded by their (body's) points of contact between the support surface; For example, during standing, the base of the support is the quadrangle bounded by the heels and the toes. For static equilibrium, the position of the horizontal projection of the body's COM must lie within the base of support, and all of the forces on the body are balanced so that one's body tends to stay in the desired position and orientation (static equilibrium). During locomotion, the projection of the COM rarely lies within the base of support but is continuously regulated to maintain dynamic equilibrium. Moving in a controlled way during dynamic equilibrium includes automatic responses to unexpected disturbances, as well as anticipatory postural adjustments. Although postural coordination occurs by fast, automatic pathways, postural coordination can be significantly influenced by long-term training, practice, and previous experiences [6, 7].

We hypothesized that increased balance and balance confidence in participants between 60 – 80 years old would result following several weeks of balance training targeting vision and support surface somatosensory cues, base of support, as well as static and dynamic balance. Here, we quantified balance and balance confidence in terms of two well-known, standard measures: the Balance Error Scoring Systems (BESS) and the Activities-Specific Balance Confidence (ABC) Scale.

METHODS

All experiments for this study were conducted within the Center for Biomechanical & Rehabilitation Engineering (CBRE) at the University of the District of Columbia (UDC) and the protocol was approved by the UDC Institutional Review Board (979744-1). Here, we describe the results for 11 female (69.8 years old +/- 6.3 years) and 3 male participants (64.7 years old +/- 3.5 years old) enrolled in this on-going study. Most developed world countries have accepted the chronological age 65 years old and above defines the age-group for "elderly" individuals; our average age for participants was within this range.

Participants completed a 6-week exercise routine which consisted of two, 30 minute sessions/week. During the sessions, the participants worked with the principal investigator and two trainers (research assistants) which also served as spotters. Further, during the training sessions, the subjects donned a harness attached to a NaviGAITor multidirectional partial bodyweight support system to prevent them from falling (as shown below in Figure 1, left). Over the course of several weeks, training progressively increased in difficulty. The training included the following:

Training I. Walking

- Walking straight ahead, side-stepping to right, walking backwards, side-stepping to left and repeating ten times
- Walking straight ahead (tandem foot placement), side-stepping to right, walk backwards (tandem foot placement), side-stepping to left and repeating ten times
- Walking eyes-closed, forward and back
- Walking eyes-closed, forward and backwards over foam obstacle

Training II. Foam Exercises

- Ankle raises on the foam, three sets of ten (eyes-open/closed)
- Forwards and backwards step-ups on and off of the foam, three sets of ten each (eyes-open/closed)

- Isolated balancing on each leg (front, side, and back leg kicks), three sets of ten each (eyes-open/closed)

Training III. Walking over obstacles and more foam exercises

- Walking eyes-closed on harder foam
- Walking eyes-closed on harder foam and over compliant foam obstacle
- Step ups on high (10 inch) foam step, three sets of ten (eyes-open/closed)
- Squats (eyes-open/hard surface; eyes-closed/hard surface; eyes-open/foam surface; eyes-closed hard surface) ten repetitions each
- Spinning in chair, then walking on hard foam

Figure 1. NaviGAITor harness system (left); Administering BESS assessment (right)

At baseline (1st session of week 1), and during a 3rd session during weeks 3 and 5, each participant was assessed individually. Standard assessments included the Balance Error Scoring Systems (BESS) and the Activities-Specific Balance Confidence (ABC) Scale. The BESS assessment utilized double-leg, single-leg, and tandem stances as the participant stood on either hard or foam surfaces, all with eyes closed with hands on their hips. The number of deviations from upright were counted as ‘errors’ for six, 20 second trials. Some examples of errors to be counted were the following: moving the hands away from one’s sides/off of the iliac crests, opening one’s eyes, stepping/stumbling, hip abduction or flexion beyond 30^o (e.g., crouching), remaining out of the proper testing position for over 5 seconds. Each error was given a point or 1, and errors were counted throughout each trial. A higher score could be interpreted as lesser ability to balance; conversely, a lower score (i.e., fewer deviations) could be interpreted as a better ability to balance.

This assessment allowed us to determine if the training was effective for increasing the individual’s balance. Each participant was assessed prior to training taking place and therefore served as their own control. In other words, baseline (or control data) was taken for each and every individual at week 1, prior to training. Each participant was assessed at week 3, and then again at the end of week 5 at the conclusion of their training. In this way, each participant (i.e., data collected at week 1 in the initial session, prior to training) served as their own control. To assess participant balance confidence, the ABC scale was used. The survey questions included (among others), "How confident are you that you will not lose your balance or become unsteady when you: Walk around the house? Walk up or down stairs? Bend over and pick up a slipper? Are bumped into by people as you walk?”. From the total score, 100% = high level of physical function; 50-80% = moderate function; < 50% = low function; and, in general, < 67% indicated risk for falling. Each participant was blind to their ABC survey answers from their previous assessments.

For the analysis, for the female and male groups, we determined collective means, standard deviations, and ranges in BESS scores for the 1st, 2nd and 3rd assessments. Differences were compared by using statistical analysis (t-tests) between the 1st and 3rd assessments. For the ABC surveys, we determined collective means and ranges for the 1st, 2nd and 3rd assessments.

RESULTS

Figures 2 and 3 show the means and standard errors of the BESS scores male and female participants, respectively.

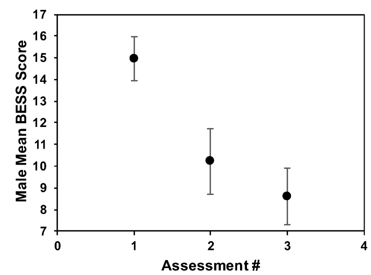

Figure 2. Averaged Male BESS assessment results (n = 3) as a function of assessment: Assessment #1 (baseline at week 1), Assessment #2 (week 3), Assessment #3 (final at the end of week 5) with standard errors of the mean shown.

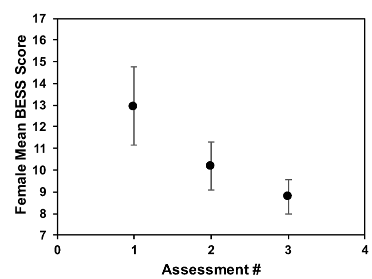

Figure 3. Averaged Female BESS assessment results (n = 11) as a function of assessment: as a function of assessment: Assessment #1 (baseline at week 1), Assessment #2 (week 3), Assessment #3 (final at the end of week 5) with standard errors of the mean shown.

Table 1 shows the BESS assessment means, maximum and minimum values, and ranges of values for assessments 1, 2, and 3 for both male and female participant groups. Table 2 shows the ABC survey means, maximum and minimum values, and ranges of values (as percentages, i.e., percent balance confidence) for assessments 1, 2, and 3 for both male and female participant groups.

Table 1. BESS Assessment: Mean, maximum and minimum values, and range for male and female participants as a function of assessment number.

	Male (n = 3)			Female (n = 11)		
	Assessment 1	Assessment 2	Assessment 3	Assessment 1	Assessment 2	Assessment 3
Mean	15.0	10.2	8.6	13.0	10.2	8.8
Maximum	17.0	13.2	10.2	23.2	16.3	12.7
Minimum	13.7	8.2	7.0	6.2	5.8	5.7
Range	3.3	5.0	3.2	17.0	10.4	7.0

Table 2. ABC Survey: Mean, maximum and minimum values, and range for male and female participants as a function of assessment number. Numbers shown are percentages.

	Male (n = 3)			Female (n = 11)		
	Assessment 1	Assessment 2	Assessment 3	Assessment 1	Assessment 2	Assessment 3
Mean	87.6	90.4	91.3	93.4	92.4	92.9
Maximum	97.5	98.9	98.1	99.4	98.3	98.1
Minimum	76.9	80.0	82.5	79.4	81.3	73.8
Range	20.6	18.9	15.6	20.0	17.0	24.4

An observation was that we had many more female participants than males; this continues to be the case in our ongoing study.

DISCUSSION

We had observed that, even in healthy seniors, balance could be improved with the use of sensory training as observed from our BESS results. Specifically, a lower BESS score (i.e., fewer deviations) at assessment #3 (final assessment) compared to the initial, baseline/control (assessment #1) could be interpreted as a better ability to balance.

For females, in comparing the initial assessment versus the final assessment, there was a significant decrease in BESS scores ($df = 12$, $t = -2.1$, $p < 0.05$). For males, in comparing the initial assessment versus the final assessment, there was a significant decrease in BESS scores ($df = 3$, $t = -3.4$, $p < 0.05$); having more male participants would only increase our confidence in this finding.

Table 1 shows that there was a range in BESS scores, in particular, the female group had a range of 17 errors for the 1st assessment (max. score 23.2 and min. score of 6.2). For the female participants, that already had low BESS scores at baseline (Assessment #1), the changes over the 3 assessments were less pronounced and insignificant. However, the opposite was true for female participants that started off with lower BESS scores (indicating a lesser ability to balance). A 12th female participant was not included in the averaged data shown due to the fact that the result was an outlier. However, she showed the largest BESS changes: 41.2 errors (Assessment #1); 19.4 errors (Assessment #2); 17.3 errors (Assessment #3). Further, this same participant also showed the largest change in balance confidence, as indicated by the ABC survey: 42.5% (Assessment #1) to 62.2% (Assessment #3).

From Table 2, significant changes in balance confidence were not observed. This was likely due to the fact that we were working with healthy participants, so most participants were (in general) confident about their balance. The means for both male and female groups were around 90% balance confidence. However, when we work with an impaired population (e.g., chronic stroke survivors), we may see more pronounced changes in confidence over the several weeks of training.

Our results led us to project that key experiences which seniors could do while at home (i.e., outside of a clinical setting) to help them improve their balance could involve, for example, training which utilizes eyes-open/closed and balancing activities on compliant surfaces, such as foam.

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