Aging Clinical and Experimental Research

Games-based biofeedback training and the attentional demands of balance in older adults*

Eric Heiden and Yves Lajoje

School of Human Kineitcs, University of Ottawa, Ottawa, Canada

ABSTRACT. ***Background and aims:*** *Programs designed to improve balance in older adults may function by improving general fitness (strength, endurance, range of motion) and also changing the attentional demands of postural control. Research in previously sedentary older adults cannot differentiate between changes in balance ability resulting from improved fitness or reduced attentional demands. A training program of games-based balance biofeedback was given to nine older adults with previous exercise experience.* ***Methods:*** *Training consisted of sixteen sessions (twice weekly for eight weeks) of 30 minutes each. Postural sway (force plate measurement), attentional demands (dual task paradigm), the Community Balance and Mobility Scale (CB&M), and the six minute walk test were measured in pre, post and retention tests.* ***Results:*** *Participants in the training group significantly decreased their reaction time from pre to post testing in a dual task paradigm compared to a control group. The training group also significantly increased their scores on the CB&M scale compared to control participants. The decreased reaction times and increased CB&M scores observed in the training group were maintained through a two week retention period. Changes in reaction time were significantly correlated with changes in CB&M score. Six minute walk distance increased significantly in both groups and did not appear to result directly from the training program.* ***Conclusions:*** *Games-based balance biofeedback training using a range of training postures can significantly improve functional balance in exercise trained older adults by reducing the attentional demands of postural control.*
(Aging Clin Exp Res 2010; 22: ###-###)

INTRODUCTION

Accidental falls constitute a major health concern for older adults. Recent studies estimate that up to 40% of older adults living at home will experience an accidental fall (1, 2). Following an accidental fall, older adults are more likely to experience serious injuries such as bone fractures, resulting in hospital admission and death (1, 2). In many cases, accidental falls are recognized as preventable and recent research has focused on the use of physical activity as a means to prevent accidental falls and maintain the independence and quality of life of an aging population (3, 4).

Although changes in the capacity for physical activity are associated with the aging process, there appears to be clear evidence that weakness and deconditioning in older adults can be effectively moderated by voluntary physical activity, and a great deal of study has been directed toward remedial exercise programs designed to reduce fall risk (2-4). While recent reviews appear to support fairly clear guidelines for improving muscle strength and cardiovascular endurance (3, 4), guidelines for improving balance remain elusive (2, 5).

Balance has been defined as a multi-dimensional construct, depending on the coordinated function of several body systems including vision, proprioception, vestibular information, muscular function, and energy systems (6). Each of these systems has been shown to exhibit some form of age-related decline (1, 2) leading to balance problems. But more recently the notion of attention and the capacity of the central nervous system to integrate information from various systems (6, 7), has been investigated as a source of age-related balance difficulties. Recent evidence suggests that the ability to integrate information and generate the coordinated actions necessary to main-

*Redundant or duplicate publication: A portion of this work was presented in poster format at the Virtual Rehabilitation 2009 International Conference in Haifa, Israel; Heiden E, Lajoie Y, Nativ A. Games-based biofeedback training - applications in rehabilitation and fall prevention. IEEE: Virtual Rehabilitation International Conference 2009, p. 215.

Key words: Attentional demands, balance training, CB&M scale, reaction time.

Correspondence: Eric Heiden, Msc, Department of Kinesiology, McMaster University, 1280 Main Street West, Hamilton, Ontario, Canada L8S 4K1.

E-mail: heidene@mcmaster.ca

Received September 23, 2009; accepted in revised form November 28, 2009.

First published ahead of print December 14, 2009 as DOI: 10.3275/6733

tain balance declines with age (7-9). Studies exploring the potential of specific exercise training to improve the balance of older adults have focused on the attentional requirements of balance as an outcome measure (10, 11).

Attentional demands of balance tasks, and age-related changes in attentional dynamics, can be assessed by means of the dual task paradigm (7, 9, 12, 13). Dual task paradigms investigating balance generally employ a primary postural task, and a secondary cognitive or reaction time task. When participants are instructed to consider the primary task as their first priority, attentional demands are measured by effects on the secondary task (7, 12). Lajoie (10) instructed participants to prioritize quiet standing and measured the attentional demands of this task according to changes in a secondary probe reaction time task. Changes in secondary task performance over a period of training have been interpreted as a change in the attentional demands of the primary task (10, 11).

Two recent studies have measured the attentional demands of balance tasks in order to assess the effectiveness of balance training exercises in older adults. Lajoie (10), and Bisson et al. (11) measured attentional demands and functional balance scores before and after training with computerized biofeedback and virtual reality balance training programs. Results from both studies suggest that augmented sensory feedback allowed previously sedentary older adults to improve their functional balance by improving multisensory integration and body schema (10, 11). Recent studies using biofeedback training programs have incorporated computer games in order to improve motivation and to intensify practice (11, 14). Previous biofeedback training programs have focused on one or two training postures, most commonly standing with the feet together or standing with the feet shoulder width apart (10, 11, 15). However, a recent review of balance training programs in older adults conducted by Howe et al. (5) identified a wider range of postures, including tandem stance, single leg support, and dynamic stepping as being key determinants of functional balance performance in older adults. A balance training system that is capable of incorporating computer games and multiple training postures may thus provide a superior training environment for reducing the attentional demands of postural control and improving functional balance in older adults.

The multi-dimensional nature of balance presents some difficulty in interpreting the effects of exercise training. Measures of functional balance evaluate a composite of muscular strength, endurance, range of motion and attentional dynamics, and changes in a functional balance score are often difficult to attribute to a specific balance element. Previous studies of balance training in sedentary older adults have shown functional improvements resulting from a wide variety of interventions including computerized biofeedback (10, 11), virtual reality (11), tai chi (15) and more traditional exercise programs focused on strength and aerobic endurance (16, 17). Functional balance improvements in previously sedentary older adults may be attributable to the addition of physical activity and accompanying changes in general fitness rather than the specific mode of training. Reducing the attentional demand of postural control has been identified as a possible avenue for improving functional balance in older adults (7, 10, 11). However, in previously sedentary older adults, improvements in functional balance occur at least in part through changes in fitness and thus are not easily attributed to changes in attentional demands. Balance training programs applied to active older adults may provide more specific insight into whether a games-based biofeedback training program can improve functional balance by reducing the attentional demands of postural control.

The Community Balance and Mobility Scale (CB&M) is a high-level functional balance scale developed for community-dwelling patients with traumatic brain injury (18). In addition to items evaluating strength, endurance and range of motion, the CB&M includes dual task items that are intended to evaluate balance performance under attentionally demanding conditions. The CB&M has recently been used to assess functional balance performance in community-dwelling older adults (11). The 6 minute walk test is a valid and reliable measure of composite fitness that has been shown to capture aspects of muscle strength, endurance, and flexibility in older adults (16, 17, 19). Changes in functional balance resulting from an exercise program that improves fitness would be evident on a composite fitness scale such as 6 minute walk distance. However, changes in functional balance scores occurring independently of fitness could be more confidently attributed to changes in attentional dynamics.

The goal of the present study is to examine the effects of a balance training program using games-based biofeedback in exercise-trained older adults and determine whether any resulting changes in the attentional demands of posture and functional balance are independent of more general physical fitness. This study tests the hypothesis that older adults with experience in an exercise program will improve their functional balance following supplementary balance training with augmented sensory feedback. Furthermore, it is expected that the changes in attentional demands of posture (dual task reaction time) will be associated with improvements in a high-level functional balance scale (the CB&M) and occur independently of a composite fitness measure (6 minute walk distance).

METHODS

Participants

Participants were 16 community-dwelling older adults (mean age 77 years) recruited from a chair exercise program offered by a local community center. Two identical sections of the program, taught by the same instructor were offered by the community center. The first section was randomly selected as the training group and nine participants (5 females and 4 males) were recruited from this section. Seven participants (6 females and 1 male) were recruited from the second section as a control group. The program instructor remained unaware of the training/control group assignments for the duration of the study. The chair exercise program consisted of twice-weekly hour-long sessions and included seated exercises for cardiovascular endurance, strengthening of the upper and lower body with elastic and light (1-5 lbs.) weights and stretching exercises. All of the participants had been attending the chair exercise program consistently for at least the previous 16 weeks. Informed consent was obtained at an initial interview prior to testing and volunteers were excluded from participating in the study if they reported diabetes, neurological or sensory disorders, uncontrolled cardiovascular disease, muscular or skeletal problems that limited daily activity, or a score below 25 on the Folstein Mini-Mental State Exam (MMSE). At the initial testing session (pre testing), participants in the training group did not differ significantly from the control group in their age ($t(14)=0.99$, $p>0.05$), CB&M scores ($t(8.02)=0.58$, $p>0.05$ - equal variances not assumed), 6 minute walk distance ($t(14)=0.98$, $p>0.05$), age ($t(14)=0.99$, $p>0.05$) or MMSE scores ($t(14)=0.90$, $p>0.05$). All of the participants continued to attend their regular chair exercise sessions throughout the study.

Equipment and Testing Protocol

The pre testing session consisted of a dual task paradigm with measures of postural sway and reaction time, the CB&M scale, and a 6 minute walk test. The same procedures were repeated at the end of the training period, or after a period of eight weeks for the control group (post testing), and once again for both groups following a two week retention period (retention testing). In the dual task paradigm participants stood on an AMTI force platform with their feet together and wearing shoes. Participants were instructed to move as little as possible and to consider minimizing postural sway as their primary task. Data from the force platform was sampled at 500 Hz to an online digital program which recorded centers of pressure (COP) in the anterior/posterior (A-P) and lateral (Lat.) directions. The root mean square (RMS) of COP displacement for each axis was calculated off-line using a custom computer software program. The secondary task of the dual task paradigm consisted of a probe reaction time procedure where participants made a spoken response "TOP" as quickly as possible following an auditory stimulus. An auditory stimulus "BEEP" was generated by a digital speaker (1 KHz, 80 ms duration) and recorded, along with the response, in mp3 format by a digital voice recorder. Reaction time was defined as the period between the onset of the stimulus and the beginning of the spoken response and calculated using a computerized sound editing program. Three trials lasting one minute each and including 7-9 randomly spaced reaction time stimuli were recorded for a total of 24 reaction times. The CB&M scale was administered by the experimenter and videotaped for subsequent analysis. Videos of the CB&M scale were randomly ordered and scored by a Certified Kinesiologist experienced with the scale and blinded to group membership and test period. The 6 minute walk test was conducted in a gymnasium of known circumference, where participants walked within clearly defined lanes and distance was measured to the nearest centimetre. Walking direction and time of day were kept constant for each test period.

Training Protocol

Participants in the training group attended sixteen 30 minute sessions, twice weekly over eight weeks, of games-based balance biofeedback exercise using a customized training system manufactured by NeuroGym Technologies. Participants stood on two pressure sensors, whose input was relayed to a computer game displayed on a 17-inch monitor placed at eye level approximately 60 cm away. Each pressure sensor (25 x 10 x 1.5 cm) could be placed independently in a variety of orientations and contained a single load cell which was sampled at 300 Hz. The difference in signal between the two sensors was calculated online with an integration period of 20 ms and used to control a computerized tennis game (pong). While standing on the pressure sensors participants were able to control a virtual paddle by shifting their weight. The object of the game was for participants to move the paddle, by deliberately shifting their weight, in order to intercept a randomly moving ball. Five postures, requiring weight shifts in the A-P (tandem standing, single support left leg, single support right leg) or Lat. (feet shoulder width apart) directions, and a dynamic stepping routine where participants performed lateral steps while standing between pressure sensors placed at 2 x shoulder width apart were used in the training program. These postures were chosen to cover the range of movement skills thought to underlie functional balance (5). In each training session, participants played the tennis game for 4 minutes in each posture. After each game, the orientation of the sensors was changed for the next training posture and participants were given the opportunity to rest if they desired. Postural support was available in the form of two chair backs placed near the participant's right and left hands. Participants' use of the chair backs was recorded by the experimenter for each game as continuous (hand on chair throughout the game), frequent (hand on chair for more than half the game), occasional (hand on chair for less than half the game), or none. Each participant started training with the tennis game at speed setting 3, where the ball moved at 5 cm/s across the 15 cm game screen. The game software recorded the percentage of successful interceptions, and participants achieving over 80% success in a game for two consecutive training sessions had their speed setting increased to a maximum of setting 5 (7.5 cm/s). Participants training at speed setting 5 were encouraged by the experimenter to minimize their use of the postural support.

Data Analysis

Data analysis was carried out using SPSS 15.0 for Windows. Repeated measures analysis of variance (ANOVA) with factors Group (two levels) Time (three levels) and Direction (two levels) was used for COP displacement. Separate repeated measures ANOVAs with factors Group (two levels) and Time (three levels) were conducted for reaction time, CB&M score and 6 minute walk distance. Subsequent pairwise comparisons were made using the Bonferroni adjustment for multiple comparisons. Gender was not considered as a factor based on previous work by Bisson et al. (2007) that did not find significant gender effects in a similar population of older adults. All statistical analyses were carried out with an alpha level of 0.05.

RESULTS

Training Progression

All of the participants in the training group had progressed to playing the game at speed setting 5 after 4 weeks of training. After 8 weeks of training none of the participants were using postural support for Lat. weight shifting with the feet shoulder width apart and dynamic stepping at 2 x shoulder width. After 8 weeks of training, all of the participants were using either frequent or occasional support for the other training postures.

Postural Sway

There were no significant differences between the training and control groups for postural sway in the A-P ($t(14)=0.32$, $p>0.05$) or Lat. ($t(14)=1.87$, $p>0.05$) directions at the initial testing session (pre testing). A three-way ANOVA Group (Training, Control) x Time (Pre, Post, Retention) x Direction (A-P, Lat) with repeated measures on the last two factors was used to analyze participants' postural sway. There was not a significant between subjects effect of Group ($F(1,14)=0.51$, $p>0.05$). There was a significant main effect of Direction ($F(1,14)=6.54$, $p<0.05$) with RMS values being higher in Lat. direction for all of the conditions (Fig. 1). There was no significant main effect of Time ($F(2,28)=0.19$, $p>0.05$) and there were no significant interactions.

Reaction Time

A two-way ANOVA Group (Training, Control) x Time (Pre, Post, Retention) with repeated measures on the last factor was used to analyze participants' reaction times in the dual task condition. There was no significant between subjects effect of Group ($F(1,14)=0.44$, $p>0.05$). There was a significant main effect of Time ($F(2,28)=4.27$, $p<0.05$) and a significant interaction of Group and Time ($F(2,28)=8.54$, $p<0.05$). The Training group showed a large reduction in mean reaction time from Pre to Post testing relative to the Control group (Fig. 2) that was maintained at Retention testing.

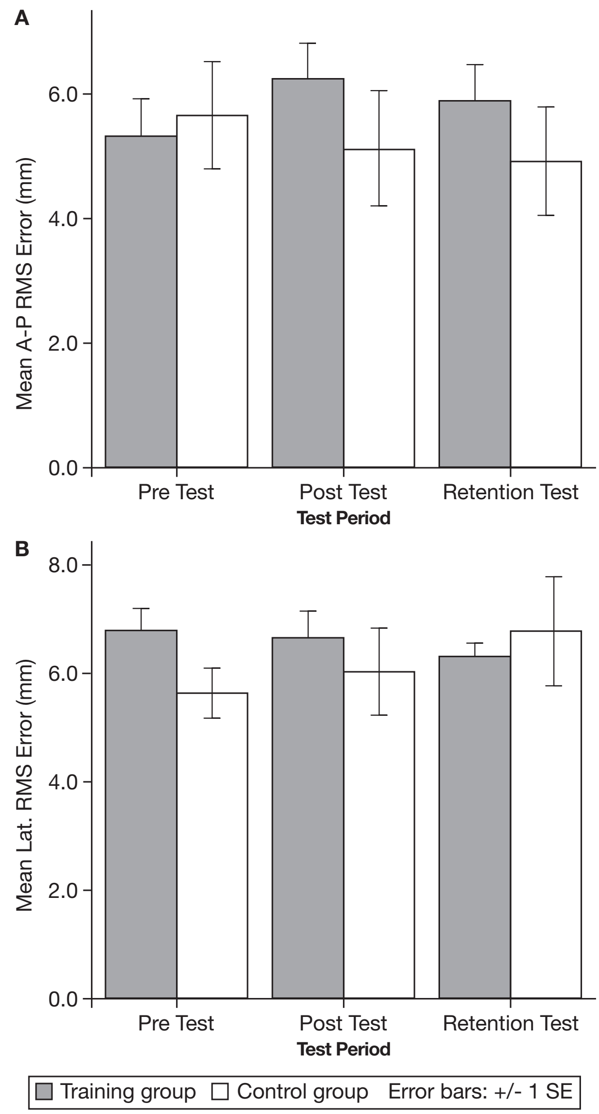

Fig. 1 - *Mean RMS displacement for center of foot pressure in the anterior/posterior (A-P) direction (A) and the lateral (Lat.) direction (B) for the training group and control group at pre testing, post training and after a two week retention period.*

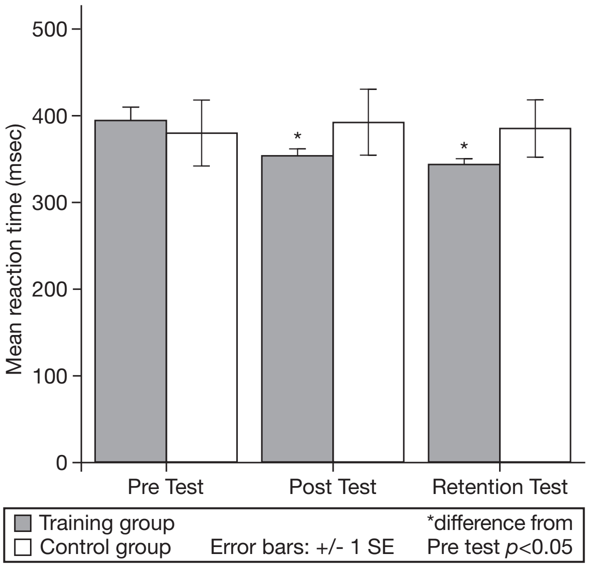

Fig. 2 - *Mean dual task reaction time for the training group and control group at pre testing, post training and after a two week retention period.*

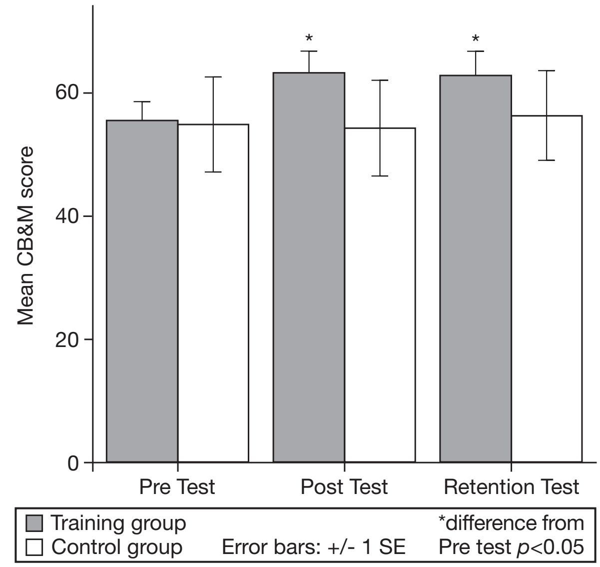

Fig. 3 - *Mean CB&M scores for the training group and control group at pre testing, post training and after a two week retention period.*

Functional Balance and Composite Fitness

Two separate two-way ANOVAs Group (Training, Control) x Time (Pre, Post, Retention) with repeated measures on the last factor were used to analyze functional balance (CB&M scores) and composite fitness (6 minute walk distance). For the CB&M scores there was no significant between subjects effect of Group (F(1,14)=0.47, p>0.05). There was a significant effect of Time (F(2,28)=8.32, p<0.05) and a significant interaction of Group and Time (F(2,28)=6.75, p<0.05). The training group showed a mean increase of 7.89 points on the 96 point CB&M scale in mean CB&M score from Pre to Post testing (Fig. 3) which was maintained at Retention testing. For the 6 minute walk distance there was no significant between subjects effect of Group (F(1,14)=0.10, p>0.05). There was a significant effect of Time (F(2,28)=7.17, p<0.05) with both groups showing an increase in 6 min walk distance from Pre to Post testing (Fig. 4) that was maintained at Retention testing. However, there was not a significant interaction of Group and Time (F(2,28)=1.38, p>0.05).

Reaction Time, Functional Balance and Composite Fitness

Changes in reaction time, CB&M score, and 6 minute walk distance were calculated for each participant by taking the absolute value of the difference from Pre to Post testing. Pearson correlations were calculated for relationships between reaction time and CB&M score and between 6 minute walk distance and CB&M score. The observed changes in reaction time from Pre to Post testing were significantly related to changes in CB&M score by a moderate positive correlation (r=0.45, p<0.05, one-tailed) with larger changes in reaction time being

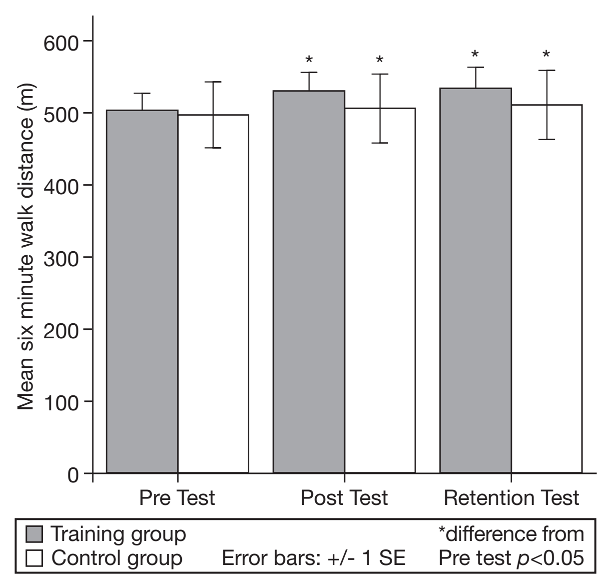

Fig. 4 - *Mean 6-minute walk distance for the training group and control group at pre testing, post training, and after a two week retention period.*

associated with larger changes in CB&M score. Changes in 6 minute walk distance were not significantly correlated with changes in CB&M score (r=0.18, $p>0.05$, one-tailed).

DISCUSSION

Sway values in the present study were significantly larger in the Lat. direction than in the A-P direction. This finding is most likely due to the narrow base of support inherent in the feet together standing position. Bisson et al. (11) found significantly greater Lat. sway in a feet together position compared to standing with the feet shoulder width apart. Sway measures did not change significantly following the training program, a result that is consistent with previous studies employing dual task paradigms following computerized biofeedback and virtual reality training (10, 11). Muscular strength, endurance, and the ability to control joint motion around the ankles and hips are important aspects of controlling postural sway while standing with the feet together (6). While the present study did not directly measure muscle strength, it is possible the participants in the training group did improve some subtle aspects of postural control. Waddington and Adams (20) showed that 5 weeks of wobble board training in older adults resulted in an improved ability to discriminate between ankle joint angles. In the present study, participants in the training group may have improved their ability to recognize changes in joint angles at the hips, knees and ankles associated with controlling posture. These improvements may have helped trained participants develop a more automatic postural control strategy that, while not directly impacting the amount of sway, resulted in less attention being allocated to postural control.

While participants in the training group did not change in their ability to stand with minimal sway, they did improve in their ability to respond to the unexpected auditory stimulus. Secondary task reaction time was significantly reduced at post testing for participants in the training group relative to the control group. The average decrease in reaction time of 50 ms is comparable to those observed by Lajoie (10), and Bisson et al. (11) following computerized biofeedback and virtual reality training. Participants were instructed to prioritize the postural task and consider reacting to the auditory stimulus as a secondary task. If participants had shifted their priority from the postural task to the reaction time task, an increase in sway values could have been expected to accompany a decrease in reaction time (21, 22). Participants in the training group were able to significantly decrease their secondary task reaction time while maintaining consistent sway values, suggesting that the postural task was less attentionally demanding for the trained participants (7, 12). Practice with biofeedback allowed participants in the training group the opportunity to relate visual feedback, in this case the movement of the game paddle, to movements of the body's center of pressure. Prolonged training with biofeedback may have provided participants with more detailed information about their movements than was available or recognizable through sensory channels (10, 11, 14). This augmented sensory information provided through biofeedback may have helped the trained participants develop a more detailed and reliable body schema for postural control (10). Thus the trained participants performed the primary task of minimizing postural sway with the same level of proficiency, but required less effort, evident in the reduced secondary task reaction time.

Participants in the training group made significant improvements on their CB&M scores from pre to post testing relative to the control group. The training group's improvement of 7.89 points was larger than the respective improvements of 5.7 and 5.6 points for computerized biofeedback and virtual reality training reported by Bisson et al. (11). The versatility of the NeuroGym system allowed the present study to include a more comprehensive range of training postures (5) than has been attempted in previous studies of balance biofeedback (10, 11, 15, 17). The addition of training postures such as tandem standing, single support and dynamic stepping may account for the larger improvements in functional balance seen in the present study. The significant correlation between changes in reaction time and changes in CB&M score suggests that reducing the attentional demands of postural control is linked to improvements in functional balance. This link may be particularly evident on an instrument like the CB&M, with items designed to evaluate multi-task ability (18).

Both the training group and the control group showed significant increases in 6 minute walk distance from pre to post testing. It was expected that older adults with experience in a chair exercise program would not show a significant change in their general fitness with the addition of games-based balance biofeedback training. The absence of a significant interaction effect on 6 minute walk distance suggests that the training group did not significantly improve their walking distance as a direct result of the training program. The observed increase in composite fitness for both groups may be the result of a learning effect of the 6 minute walk test, as the conditions of the test (setting and direction) remained constant for each testing period. Rubenstein et al. (16) reported non-significant increases in 6 minute walk distance, averaging 15 m, for non-exercising control participants. The average increases from pre to post testing of 9.5 m and 27 m respectively for the control and training groups in the present study may reflect a familiarization with the pacing demands of the test. It is also possible that the larger increase observed in the training group may reflect a training-induced change in lower extremity strength or some other gait variable not measured by the present study (3, 5, 23).

Ready for press

Signature ....

CONCLUSION

The results of the present study suggest that balance training with the NeuroGym system of games-based biofeedback is an effective means of improving the functional balance of community-dwelling older adults. By increasingly the automaticity of postural control, balance biofeedback training may facilitate the functional balance responses that are instrumental in avoiding accidental falls. Furthermore, specific balance training with games-based biofeedback appears to provide an additional benefit to more traditional chair exercise programs. These results highlight the importance of a comprehensive approach to exercise training for fall prevention that includes elements of muscle strength, endurance, flexibility, and specific training for postural control.

REFERENCES

1. Rubenstein LZ. Falls in older people: epidemiology, risk factors and strategies for prevention. Age Ageing 2006; 35 (S2): 37-41.
2. American Geriatrics Society, British Geriatrics Society, and American Academy of Orthopaedic Surgeons Panel on Falls Prevention. Guideline for the prevention of falls in older persons. J Am Geriatr Soc 2001; 49: 664-72.
3. Spriduso WW, Cronin DL. Exercise dose-response effects on quality of life and independent living in older adults. Med Sci Sports Exerc 2001; 33: s598-608.
4. Carter ND, Kannus P, Khan KM. Exercise in the prevention of falls in older people. Sports Med 2001; 31: 427-38.
5. Howe T, Rochester L, Jackson A, et al. Exercise for improving balance in older people. Cochrane Database Syst Rev 2007; 4.
6. Balasubramaniam R, Wing AM. The dynamics of standing balance. Trends Cogn Sci 2002; 6: 531-6.
7. Woollacott M, Shumway-Cook A. Attention and the control of posture and gait: A review of an emerging area of research. Gait Posture 2001; 16: 1-14.
8. Lajoie Y, Teasdale N, Bard C, Fleury M. Attentional demands for static and dynamic equilibrium. Exp Brain Res 1993; 97: 139-44.
9. Teasdale N, Simoneau M. Attentional demands for postural control: The effects of aging and sensory reintegration. Gait Posture 2001; 14: 203-10.
10. Lajoie Y. Effect of computerized feedback postural training on posture and attentional demands in older adults. Aging Clin Exp Res 2004; 16: 1-6.
11. Bisson E, Contant B, Sveistrup H, Lajoie Y. Functional balance and dual-task reaction times in older adults are improved by virtual reality and biofeedback training. Cyberpsychol Behav 2007; 10: 16-23.
12. Fraizer EV, Mitra S. Methodological and interpretive issues in posture-cognition dual-tasking in upright stance. Gait Posture 2008; 27: 271-9.
13. Quant S, Adkin AL, Staines WR, Maki BE, McIlroy WE. The effect of a concurrent cognitive task on cortical potentials evoked by unpredictable balance perturbations. BMC Neurosci 2004; 5: 1-12.
14. Herndon A, Decambre M, McKenna P. Interactive computer games for treatment of pelvic floor dysfunction. J Urol 2001; 166: 1893-8.
15. Wolf SL, Barnhart HX, Kutner NG, McNeely E, Coogler C, Xu T. Reducing frailty and falls in older persons: An investigation of tai chi and computerized balance training. J Am Geriatr Soc 1996; 44: 489-97.
16. Rubenstein LZ, Josephson K, Trueblood P et al. Effects of a group exercise program on strength, mobility, and falls among fall-prone elderly men. J Gerontol A Biol Sci Med Sci 2000; 55: 317-21.
17. Baker MK, Kennedy DJ, Bohle PL et al. Efficacy and feasibility of a novel tri-modal robust exercise prescription in a retirement community: a randomized, controlled trial. J Am Geriatr Soc 2007; 55: 1-10.
18. Howe JA, Inness EL, Venturi A, Williams JI, Verrier MC. The community balance and mobility scale - a balance measure for individuals with traumatic brain injury. Clin Rehabil 2006; 20: 885-95.
19. Bautmans I, Lambert M, Mets T. The six-minute walk test in community dwelling elderly: influence of health status. BMC Geriatr 2004; 4: 6.
20. Waddington GS, Adams RD. The effect of a 5-week wobble-board exercise intervention on ability to discriminate different degrees of ankle inversion, barefoot and wearing shoes: A study in healthy elderly. J Am Geriatr Soc 2004; 52: 573-6.
21. Maki BE, Zecevic A, Bateni H, Kirshenbaum N, McIlroy WE. Cognitive demands of executing postural reactions: Does aging impede attention switching? NeuroReport 2001; 12: 3583-7.
22. Maylor EA, Allison S, Wing AM. Effects of spatial and nonspatial cognitive activity on postural stability. Br J Psychol 2001; 92: 319-38.
23. Latham N, Bennett D, Stretton C, Anderson C. Systematic review of progressive resistance strength training in older adults. J Gerontol A Biol Sci Med Sci 2004; 59: 48-61.