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A Comparative Analysis of Changes in Postural Control Following Training using the Wii Balance Program and Standardized Falls Prevention Programs

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A COMPARATIVE ANALYSIS OF CHANGES IN POSTURAL CONTROL FOLLOWING TRAINING USING THE WII BALANCE PROGRAM AND STANDARDIZED FALLS PREVENTION PROGRAMS

By

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Declines in balance and postural control are believed to be the major neuromuscular factors that contribute to an increased risk of falling with age. Balance training has been reported to be an effective tool for increasing these parameters in older fallers, but its effectiveness in improving balance in higher-functioning, independent-living elders is uncertain. PURPOSE: The purpose of this study was to compare the impact of two formal balance-training interventions (Tai Chi and standardize balance exercise program [SBEP]) and an activity-promoting video game, the Wii Fit balance program. METHODS: Twenty-nine healthy, independent seniors (72.10 ± 7.80) were randomly assigned to eight weeks of Tai Chi, SBEP or Wii training twice per week. Outcome measures included four field tests, force plate postural sway (COP) and dynamic posturography (DP). Results: No significant differences between groups or across time were found in any field test. No differences were seen between groups for any COP measures. Significant differences were seen across time for the entire sample total COP area and velocity. In three of the four anterior/posterior displacement variables and both velocity variable significant differences were also seen. For the medial/lateral variables, one displacement and one velocity

measure was significant. In the DP, no significant time x group interactions were seen for any variables. A significant improvement in the overall score (DMA), and in two of the three linear and angular measures were seen for the entire sample. Conclusion: The Wii Fit balance program, which can be performed at home, was as effective as Tai Chi and SBEP in improving postural control and balance dictated by the force plate postural sway and DP measures. This finding may have implications for exercise adherence since the at-home nature of the intervention eliminates many obstacles to exercise training.

Dedication

To my parents, for all the unconditional love and support they have provided me throughout my personal and professional life.

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Chapter 1: Introduction

The demographic shift toward an older mean age in the world population is associated with an increased incidence of falls and falls-related injuries. In the United States, the rate of fatal falls for persons 65 and older increased 35% from 1990 to 2002[1]. Impairments in balance and postural control are believed to be the major neuromuscular factors that contribute to an increased risk of falling with age.[2, 3] Both are complex motor skills that depend on sensory input (propioceptive, vestibular and visual systems), central processing (motor control), and muscle strength and power.[4] The two main functional goals of postural control are postural stability and postural orientation. Biomechanical constrains, movement strategies, sensory strategies, orientation in space, control of dynamics, and cognitive processing are all required for postural stability and orientation. One of the most important biomechanical constrains on postural control involves controlling the body's center of mass (COM) with respect to its base of support. During stance, the limits of stability (area over which an individual can move his or her COM and maintain balance without changing the base of support) inscribe a cone-shaped pattern with the support base serving as the apex and the COM moving freely within the limits of the individual's maximum sway angle in a given plane of motion. The area of each individual's limits of stability is determined by the size of the support base, joint range of motion (ROM), muscle strength, and the sensory information available to detect the limits.[5] In elderly fallers, this cone area tends to decrease with reduced limits of stability.[6]

Three major movement strategies are used to maintain balance: the ankle strategy, where the body moves using the ankle as a flexible pendulum, commonly used to address a limited amount of sway on a stable surface; the hip strategy, where the body exerts torque at the hips to quickly move the body COM, mainly used by elderly persons attempting to manage compliant surfaces while maintaining a narrow stance and in individuals with fear of falling; and, stepping, which allows a change in the base of support.[7] The degree to which each strategy is used can be affected by the intention, experience and expectations of the individual.[5]

Many studies have reported the positive effect of physical activity-based interventions on balance. These include Tai Chi[8, 9, 10, 11, 12], sitting, standing and walking practice[13],direction-specific weight-shifting tasks[14], traditional Greek and Turkish dance programs[15, 16], balance and coordination drills[17], and functional balance training using activities like single stance, tandem gait, walking on toes and heels, walking backwards, sideways, and turning around.[3, 4] However, these interventions are underutilized by older persons since they require attendance at a formal class, which necessitates travel, adherence to a specific class schedule, and lack of information concerning progress across the training period.[4]

Activity-promoting video games are a new-generation of active computer and video-console games, also known as “exer-gaming” (a portmanteau of exercise and gaming), which promote increased physical activity in the home. Wii Fit (Nintendo Company Ltd., Kyoto, Japan), a console exer-game released in 2007, is an activity-promoting video game that utilizes a new peripheral, the Wii balance board. The Wii balance board contains multiple pressure sensors that are used to measure the user's center of balance (the location of the intersection between an imaginary line drawn vertically through the center of mass and the surface of the balance board) and weight.

To our knowledge, there are no controlled studies that have examined the effectiveness of the Wii Fit video game as a balance training intervention. Such a home-based intervention may increase exercise adherence since it is entertaining, requires no travel or adherence to a specific class schedule, allows participation in the family environment, and fits seamlessly into today's technology-driven society.

The aim of this study was to compare changes in balance and postural control resulting from the Wii Fit balance program (Wii), a standardize balance exercise program (SBEP), and a Tai Chi program (Tai Chi). We hypothesized that the Wii Fit balance program would produce significant improvements in balance and reduced falls probability across eight training weeks, and these improvements would be significantly better than those produced by either a Tai Chi or the SBEP.

Chapter 2: Methods

Participants

A total of 40 healthy older participants, 15 men and 25 women, mean age ± SD, 72.10 ± 7.80 years, agreed to participate in the study. Individuals with any neurological impairment that would affect balance, severe cognitive impairment, severe musculoskeletal impairment, unstable chronic disease state, major depression, severe vestibular problems, severe orthostatic hypotension, or simultaneous use of cardiovascular, psychotropic and antidepressant drugs could not participate in the study. Participants had no prior experience with any balance training program, Tai Chi, or Wii. All lived independently in the surrounding communities and required no assistance in performing their activities of daily living. They were instructed not to take part in any formal exercise program for the duration of the study.

Random assignment to one of the three training groups, SBEP, Tai Chi, and Wii, was completed after an initial assessment and baseline testing. Characteristics for participants in each of the training groups and for the complete sample are presented in Table 1.

Preliminary Testing Schedule

Participants came to the lab for three visits, each lasting approximately one hour. During these visits they performed a number of tests. The order of the tests was randomized among participants; however, the testing order was held constant for each participant across testing sessions.

During their first visit participant signed an informed consent approved by the University's Subcommittee for the Use and Protection of Human Subjects. They also completed a health status questionnaire (HSQ) to confirm study eligibility. Each participant's height, weight, and blood pressure were also recorded. Finally, the participants were familiarized with, and allowed to practice, all four field tests and two laboratory tests performed during the study.

Day two began with the participant completing the Falls Efficacy Scale (FES).[18] After completion of the questionnaire, the participant performed the Timed Up and Go (TUG)[19], One-Leg Stand (OLS)[20], Functional Reach (FR)[6], and Tinetti Performance Oriented Mobility Assessment (POMA)[21]. Rest periods of 5, 7, and 10 minutes, respectively, were allowed between these tests to reduce the potential for fatigue to affect performances during any test. Procedures for these tests have been previously described in the literature.

Day three began with the completion of the Falls Risk for Older People—Community Setting (FROP-Com) assessment tool.[22] Following this, the participant performed the postural sway (PSway) and the dynamic posturography (DynP) tests. A 30-minute rest period was allowed between the tests to reduce the potential impact of fatigue on performance during the second test.

Field Tests

The methods used to administer each field test have been previously described in the literature.

Laboratory Tests

The Postural Sway test. [23, 24] PSway was assessed using a portable force platform (AccuSway System, Advanced Mechanical Technology, Inc., Watertown, MA). The force platform detected the medial–lateral and the anterior–posterior displacement of the center of pressure (COP)[25] as well as time-to-boundary (TTB) measurements.[26, 27] The participant was asked to stand on the force platform without shoes, quietly, gazing straight ahead, with feet comfortably spaced, and arms by his or her sides. He or she performed three 10s repetitions of the double-leg stance test with eyes open.

The COP parameters analyzed included: COP area; mean velocity (V_{avg}), and maximum and minimum velocities in the medial-lateral and anterior-posterior directions ($MLV_{max,}$ $MLV_{min,}$ $APV_{max,}$ $APV_{min,}$ respectively). Additionally, the mean, standard deviation, maximum and minimum excursions COP in the medial-lateral and anterior-posterior directions ($MLD_{avg,}$ MLD_{SD}, MLD_{max}, MLD_{min}, $APD_{avg,}$ APD_{SD}, APD_{max}, APD_{min}, respectively).

Dynamic Posturograhy. The participant completed a single dynamic balance test on the Proprio 5000 (Perry Dynamics, Inc., Illinois, USA) according to the procedures described by Charnock et al.[28] Briefly, the device's ultrasonic sensor belt was placed on the participant's waist with the transmitter positioned between the spinous processes of lumbar vertebra five (L5) and sacral one (S1). The participant was placed in a harness to ensure safety and then stood on the moveable platform with feet shoulder width apart. The device produced incremental increases in platform angle in random (lateral, up and down, anterior to posterior, clockwise, and counter clockwise) directions. The speed was gradually increased from 12.65 deg·s^{-1} to 126.4 deg·s^{-1}. The test lasted for a maximum of 120 s. As a safety precaution, the test automatically stopped if the platform sensors detected movement of 7.6 cm (in any direction) in 0.25 seconds or 12.7 cm of movement in one direction at any time. The sensor recorded every 0.25 second (480 total readings during the two minute test) and the total inches of movement (anterior/posterior, superior/inferior, and lateral) were computed. The data provided by the Proprio 5000 included the dynamic motion analysis (DMA) score; up and down (LIN_{UD}), side to side (LIN_{Lat}), and anterior/posterior (LIN_{AP}) translational movements; and rotational movements including flexion/extension ($ANG_{Flex/Ext}$), lateral flexion ($ANG_{LatFlex}$) and core rotation (ANG_{Rot}). The DMA score was calculated using the sum of the successive translational difference scores for sensor position throughout the entire trial. If the test stopped before the two-minute time limit, the machine's software added a score of "3 inches" for each remaining 0.25 second period not completed. Every score was expressed in inches. Motion capture data has confirmed a strong correlation between the medial-lateral and superior-inferior movements of the center of mass of the body and the sacral marker of the Proprio 5000.[28]

Assessment Questionnaires

The Falls Risk for Older People—Community Setting (FROP-Com)[22] and Falls Efficacy Scale (FES)[18] were used to assess fall risk and fear of falling, respectively. Completion of the FROP-Com and FES required approximately 15 and 5 minutes, respectively.

Training

Each participant came to the training facility twice a week for eight consecutive weeks, for a total of sixteen visits. Each visit was approximately sixty minutes long and consisted of five minutes warm-up, fifty minutes of the training, and five minutes of cool-down.

The Standardized Balance Exercise Program

Of the fourteen participants randomly assigned to the SBEP, eight participants finished the training program. Three participants never began the program, one participant started but could not continue due to other time commitments, one participant had a muscle injury not associated with the training program, and one participant fell during her daily activities.

This program consisted of fourteen functional activities with a pronounced demand for balance.[3] Among the functional activities were:

1. Stepping on a compliant surface;
2. Walked forward 10 steps and pivoting 180°;
3. Alternately moving a weight between a high and low shelf situated just beyond one arm's length;
4. Turning around full circle;
5. A two leg stand;

6. Lifting an object from the floor, standing up, and placing it back on the floor at a distance beyond arm length;
7. Standing up from a chair with arms crossed over the chest;
8. Alternating single leg stands;
9. Walking on a compliant surface;
10. Walking over obstacles of different height and depth;
11. Walking while holding glass full of water;
12. Tandem walking forward along a line;
13. Walking up and down a flight of stairs; and,
14. Standing on a compliant surface.

During the 8 weeks of training, participants performed drills 1 through 7 on training day 1, and drills 8-14 on training day 2. Increases in difficulty such as reductions in base of support, closing of the eyes, increased speed of movement, increasingly unstable surfaces, and combinations of skills were used to increase the intensity of the program as necessary throughout the training period.

Tai-Chi Program

Fourteen participants were randomly assigned to the Tai Chi training program. Eleven participants finished the training program, three never started.

The Tai Chi program was based on Sun Style, originally created by Sun Lu Tang. The Sun style is one of the four main popular Tai Chi styles, namely Chen, Wu, Yang and Sun. All four styles contain the same basic principles of slow, continuous movements combined with deep diaphragmatic breathing and maintenance of an upright posture .[29] The specific form used for the participants training was one that is currently practiced and promoted by arthritis foundation's worldwide. A certified Tai Chi exercise leader taught the class throughout the study. The form taught consisted of 12 movements utilizing small forward and backward steps, as well as weight transfers from one leg to the other. The form also focused on posture alignment, slight bending of the knees and moving slowly with a gentle resistance. One of the characteristics of the Sun Style is that it utilizes high stances, limited stepping distances and multiple follow-up steps, which made it easy for the participants to learn and reduced the stresses on the knee and ankle joints.[30]

Wii Fit Balance Program

Twelve participants were randomly assigned to the Wii program. Eight participants finished the training program, 2 never started, 1 participant started but couldn't continue due to time commitments, and 1 participant didn't wish to continue since her husband, who was participating in the SBEP, had a muscle injury not associate with the training program and could not continue in the study.

This program was based on the Wii Fit game (Nintendo Company Ltd., Kyoto, Japan). The Wii Fit is divided into four categories: yoga, strength training, aerobics, and balance games. The balance game portion of the program was used for the study. The personal profile of the participant was entered into the system to allow logical progression of difficulty across the training period. The system allowed the user to map daily progress, set goals, and chart activities. The system also provided an on-screen trainer to lead the user through exercise and demonstrate proper form. The participants were instructed to step on the Wii

Fit balance board, and follow the instructions for the different games available. The list of games used for the balance program were: soccer heading where the participants had to head soccer balls thrown moving their heads from side to side; ski slalom where the participant had to ski downhill negotiating gates by shifting their body weights form side to side; ski jump where the participants had to go down a take-off ramp by bending their knees, jump by extending their knees, and attempt to land as far down on the hill as possible; table tilt where the participants had to shift body weight in multiple directions to get balls into a series of holes; tightrope walk where the participants had to cross a tightrope by marching in place and do verticals jumps by bending and extending their knees to avoid dynamic obstacles; river bubble where the participants attempted to navigate down a twisting river in a bubble by shifting their weight without bursting it on the river banks; penguin slide where the participants had to catch fish while balanced on a piece of ice by shifting their weight form side to side; snowboard slalom where the participants had to snowboard downhill passing trough gates while shifting their body weights back and forward; and, lotus focus where the participant had to remain motionless while sitting and looking at a flame. The lotus focus game was used as cool down after the training was complete. The games were based on the control of an on-screen avatar using body movements that are detected by the balance board. The system was simple to use, and allowed the participants to perform the activities without a trainer/instructor, as well as to track their progress and goals.

Each of the games described had three levels: beginner, professional and expert. Scores ranged from 1 to 4 on each level, with 4 being the highest score. The first day of training, the participants were instructed to play each game for 7 minutes. The score obtained on each game was recorded. During the second day of training the participants played 5 out of the 8 games, for 10 minutes each. The 5 games played were chosen as follow, 3 games where they scored the lowest on the first day of training, and 2 games of their choice. For the duration of the study, the participants played 5 out of the 8 games per session, for 10 minutes each. They first played the 3 games that were not played the previous session. These were then followed by the 2 games in which they produced their lowest cumulative scores. Whenever a participant reached the maximum score on a certain level, he or she was directed to play at the next level.

Statistical Procedures

Data were analyzed using separate 3 (group) x 2 (time) repeated measures ANOVAs. When statistically significant group effects or group x time interactions were detected, Bonferoni post hoc tests were used to determine the specific group differences.

Chapter 3: Results

Field Tests. Table 2 presents the results for each of the field tests used to evaluate the effectiveness of the training programs. No significant time or time x group interactions were detected.

Laboratory Tests. No differences were seen between groups for any of the COP measures. A significant increase in COP_{area} was seen for the total sample (see Figure 1). Significant differences were also seen across time for the entire sample in selected variables. Table 3 presents the pretest and post test values for each of the COP variables. As can be seen in the table, significant differences were detected in three of the four AP displacement measures (AP_{max}, AP_{min}, AP_{SD}) and for ML_{min}. All velocity variables showed significant changes across the training period with the exception of MLV_{min}.

As was the case for the COP measurements, no significant time x group interactions were seen for any DynP variables. A significant improvement in DMA score was seen for the entire sample (see Figure 2). As can be seen in Table 4, significant decreases were seen in LIN_{AP} and LIN_{UD}; while significant increases were seen in $ANG_{LatFlex}$ and ANG_{Rot}.

Chapter 4: Discussion

The principle finding of this study was that the Wii system produced similar improvements in postural control and balance to the other interventions requiring attending a formal class with the associated membership cost, need to travel, time restraints, dress requirements and lack of immediate quantifiable feedback.

Changes in balance and postural control as a result of Wii, SBEP, and Tai Chi training were evaluated using three different types of postural control and balance assessments: field tests, laboratory tests and questionnaires.

Field Tests

No significant changes were found in the field tests in response to any intervention. While the results of our study are not consistent with those of a number of previous studies which have shown significant effects on functional tests as the result of different exercise programs aiming to improve balance.[3, 9, 16, 31, 32] The difference may be explained, in part, by the inability of these tests to detect differences in fall status and lack of sensitivity to change reported in healthy, independent-living older persons. For example, Podsiadlo and Richardson[19] reported that scores under 10s for the TUG were associated with community-dwelling individuals without known pathologies, and times above 16s are predictive of increased falls risk in older community-dwelling adults.[33] Other investigators have also reported similar cutoff values for the TUG in healthy independent older individuals. Shumway-Cook et al[34] reported scores of 8.4±1.7s for non-fallers versus 22.2±9.3s for fallers from a community-dwelling older population (86.3±6.0 yrs). Steffen et al[35] reported average times of 8±2s, 8±2s, 9±3s, 9±2s,10±1s and 11±3s for active independently-living men and women 60 to 69yr, 70 to79yr, and 80 to 89yr, respectively. Finally, in a meta-analysis examining normative values for healthy, independently-living older persons, Bohannon[36] reported means (95% confidence intervals) of 8.1s (7.1–9.0s), 9.2s (8.2s-10.2s) and 11.3s (10.0s-12.7s) for individuals aged 60 to 69yrs, 70 to 79yrs, and 80 to 99yrs, respectively. The TUG mean score for our healthy, independent sample was 8.5±2.0, which when compared to the scores reported in these earlier studies allowed little opportunity for changes to occur. Additionally, the ability of the TUG to evaluate the effectiveness of interventions designed for rehabilitation has yet to be determined.[33, 34, 35, 37]

Although the OLS had been reported to be a good indicator of falls risk in community-dwelling older individuals[20, 38, 39, 40]; there are conflicting data concerning its capacity to detect changes resulting from exercise programs targeting balance. While improvements in OLS with training had been reported by some authors[9, 10, 11, 31, 41]; others have reported no response.[12, 42, 43] In his review of the impact of Tai Chi on balance and falls prevention Wu[44] reports that discrepancies in the ability of the OLS to detect changes due to training are related to the frequency and duration of training. This may explain, in part, the lack of response seen in the OLS in the current study; since limited response has been reported in other studies where the duration of the intervention was less than 10 weeks. [10, 11, 41, 42]

The high functional level of our subjects may also have reduced the potential for significant increases in the FR. Duncan et al[6] reported mean (±SD) values for men and women in the 20 to 40yr and 41 to 69yr age groups of 16.73±1.94in, 14.64±2.18in, 14.98±2.21in, and 13.81±2.20in, respectively, and a cut-off of 6.9in for fall risk. The average pretest and post-test values across all training programs in the current study were 14.80±3.10in and 15.67±4.26in, respectively, which constitute a considerably high performance values for our sample whose average age was 72.10 ± 7.80yrs. There are also questions concerning the sensitivity of the FR to training interventions. For example, of the three functional tests used by McMurdo and Johnston[45] to evaluate the impact of a home-based exercise intervention in mobility-limited elders, the FR test showed the weakest response. Additionally, when examining the capacities of the five tests, the FR, timed 50-ft walk, timed 5-step, timed floor transfer, and 5-min-walk endurance test, to evaluate mobility and disability in community dwelling older persons, only the timed 50ft-ft walk, the timed 5-step test and the 5-min-walk could discriminate among persons classified as able, decreased and disabled.

The POMA, more than any other measure used in this study, demonstrates the high performance levels of our sample and the related ceiling effect which allowed little or no margin for measuring improvement. In this study, we used the 28-point version of the test first described by Tinetti[18] where the original total cut-off score for predicting high risk of falling was 18 or less. In both portions, $POMA_{bal}$ and $POMA_{gait,}$ of the Tinetti POMA our participants scored near or at the ceiling values (16 and 12 respectively). When adding these scores, the total values were far above the cut-off value of 18, making it very difficult to see any improvement due to training in our sample. Once again, the sensitivity of the test should also be considered. While the sensitivity of this test to change has yet to be systematically assessed[46], there are some indicators of a lower sensitivity to change compared to other functional measures. In a study designed to test the POMA, the Berg Balance Scale, gait speed and the Tinetti Fall Efficacy scale, as screening methods for referring elderly individuals living in residential care facilities for detailed physical therapy evaluation and possible intervention, the POMA and Tinetti sensitivity scores (68% and 59%, respectively) fell well below the scores for the Berg Balance scale (84%) and walking speed (80%).[47] Additionally, when these researchers examined the combined capacities of these tests as a screening tool, the combination of the Berg Balance Scale and gait speed, yielded the highest sensitivity of 91%.[47]

Laboratory Tests

For DynP we observed a significant decrease for the entire sample in the DMA score and two of the three linear measurements, LIN_{AP}, and LIN_{UD}. However, there was a significant increase in two of the three angular parameters; $ANG_{LatFlex}$, and ANG_{Rot}. The reductions in linear displacement when reacting to the moving platform (base of support) of the Proprio 5000, reflect a better stabilization of the body as the participant counteracts the platform movements and maintains the center of mass within the limits necessary for the test to continue. The decrease in DMA score is consistent with findings in our laboratory that non-fallers produced significantly lower scores than fallers drawn from a similar healthy, independent-living population. They are also in agreement with other dynamic posturography results showing the positive impact of Tai Chi and balance training on linear displacement values.[48] The increases in $ANG_{LatFlex}$, and ANG_{Rot} also reflect our earlier findings that non-fallers produced greater angular values than fallers. The increases in $ANG_{LatFlex}$, and ANG_{Rot} were likely the result of improved movement strategies [49] developed during training. Different strategies for the maintenance of balance can involve the use of different musculoskeletal segments, such as raising an arm or stepping, or they may involve the use of overlapping or "nested" segments such as ankle-hip coordination for postural control.[27] Taken together, the decreases in the linear scores (DMA, LIN_{AP}, and LIN_{UD}) reflected a higher capacity to maintain balance on a moving platform as a result of the interventions; while the increases in $ANG_{LatFlex}$, and ANG_{Rot} reflect an enhanced ability to incorporate multiple body parts and increase the degrees of freedom used to achieve body stabilization and postural control.

In general, older individuals show larger COP values than younger adults.[27] There is inconsistency in the literature in interpreting COP results when studying postural control during quiet stance. For example, Horak et al associated postural stability with decreases in COP amplitude, while other authors[50, 51] have suggested that higher sway amplitudes are related to increased postural stability. Our results reveal an increase due to training for COP area, as well as an increase of the COP variability for APD_{SD} for all training conditions. These results are consistent with those suggested by Newel et al[50] and van Emmerik et al[51], who related postural stability to an increase in variability. This increased variability could be due to our training interventions producing more complex compensatory strategies (using a greater number of degrees of freedom) when maintaining postural control.[52]

Chapter 5: Summary and Conclusions

These results indicate that the Wii balance program is as effective as formalized training programs at improving balance in healthy, independent-living persons. Given the fact that the Wii program can be used at home, many of the barriers to training such as membership cost, need to travel, time restraints, dress requirements and lack of immediate quantifiable feedback are addressed, thereby increasing the likelihood of exercise compliance. Additionally, the positive responses produced in this healthy, independent-living population suggest that these interventions may serve as effective prevention tools for improving balance and reducing falls in the future.

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TABLES

Table 1
Demographics Characteristics of the Participants by Group

	Total	SBEP	Tai Chi	Wii
No. of participants	40	14	14	12
Gender	25 F/15 M	9 F/5M	8 F/6 M	8 W/4 M
Age (y)	72.10 ± 7.80	76.00 ± 7.74	69.28 ± 6.03	70.72 ± 8.46
Height (cm)	165.23 ± 9.99	166.18 ± 11.93	166.90 ± 8.37	161.90 ± 9.25
Weight (Kg)	73.81 ± 15.65	73.50 ± 20.57	75.81 ± 12.99	71.20 ± 13.01

Values expressed as mean ± SD. Abbreviations: SBEP, standard balance exercise program; Wii, Wii Fit balance program

Table 2.

Field Test Pretest and Post-test measures

	SBEP		Tai Chi		Wii Fit	
	Pretest	Post-test	Pretest	Post-test	Pretest	Post-test
TUG(s)	9.38±1.86	9.44± 1.49	8.25± 1.8	11.20± 2.1	7.71± 2.34	8.18± 2.44
OLS(s)	7.61±9.67	16.11±18.83	28.22±19.1	31.85±23.24	31.18±27.94	28.76±26.41
FR(in)	14.24±3.18	15.12± 2.86	15.90± 2.74	16.06± 3.72	13.85± 3.40	15.65± 6.22
$POMA_{BAL}$	15.00±1.60	15.63± 0.74	15.90± 0.30	16.00± 0.00	15.13± 1.46	15.13± 2.10
$POMA_{GAIT}$	11.38±0.92	12.00± 0.00	12.00± 0.00	12.00± 0.00	11.75± 1.16	11.95± 0.35

Values expressed as mean ± SD. Abbreviations: SBEP, standard balance exercise program; Wii, Wii Fit balance program; TUG, timed up-and-go; OLS, one-leg stand; FR, functional reach; $POMA_{Bal}$, balance portion of the Tinetti Performance Oriented Mobility Assessment; $POMA_{Gait}$, mobility portion of the Tinetti Performance Oriented Mobility Assessment.

Table 3. Comparison of Center of Pressure Measurements in the Total Sample before and after Training with eyes open

	Pre-training (n=27)	Post-training (n=27)	P
APD_{avg}	-0.44 ± 1.37	-0.64 ± 1.09	.453
APD_{max}	0.26 ± 0.13	0.64 ± 0.32	.000*
APD_{min}	-0.28 ± 0.20	-0.67 ± 0.32	.000*
APD_{SD}	0.12 ± 0.08	0.29 ± 0.14	.000*
MLD_{avg}	-1.72 ± 1.97	-1.81 ± 1.58	.891
MLD_{max}	0.67 ± 0.20	0.74 ± 0.22	.129
MLD_{min}	-0.71 ± 0.23	-0.81 ± 0.24	.022*
MLD_{SD}	0.30 ± 0.09	0.33 ± 0.08	.080
APV_{max}	2.99 ± 1.47	4.07 ± 1.94	.009*
APV_{min}	4.78 ± 1.67	5.56 ± 3.23	.045*
MLV_{max}	-2.81 ± 1.00	-3.99 ± 2.02	.005*
MLV_{min}	-5.14 ± 2.76	-5.72 ± 2.70	.123
V_{avg}	1.67 ± 0.57	1.99 ± 0.91	.013*
COP_{area}	0.74 ± 0.85	1.99 ± 1.27	.000*

Values expressed as mean ± SD. *P* values indicate significance. Abbreviations: APD_{avg} , anterior/posterior average displacement; APD_{max} , anterior/posterior maximum displacement; APD_{min} , anterior/posterior minimum displacement; APD_{SD} , anterior/posterior standard deviation of displacement values; MLD_{avg} , medial/lateral average displacement; MLD_{max} , medial/lateral maximum displacement; MLD_{min} , medial/lateral minimum displacement; MLD_{SD} , medial/lateral standard deviation of displacement values; APV_{max} , anterior/posterior maximum velocity; APV_{min} , anterior/posterior minimum velocity; MLV_{max} , medial/lateral maximum velocity; MLV_{min} , medial/lateral minimum velocity; V_{avg}, average velocity; COP_{area}, total displacement area for center of pressure. Displacements expressed in cm and velocities in cm/s.

Table 4. Comparison of Dynamic Posturography Measurements in the Total Sample before and after Training

	Pre-training (n=27)	Post-training (n=27)	P
DMA	866.92 ± 4.53	824.77 ± 4.54	.036*
LIN_{Lat}	630.63 ± 5.04	628.02 ± 5.32	.839
LIN_{AP}	508.37 ± 3.88	446.20 ± 2.98	.001*
LIN_{UD}	229.19 ± 1.75	210.69 ± 1.98	.021*
$ANG_{Flex/Ext}$	244.55 ± 3.86	270.82 ± 3.40	.198
$ANG_{LatFlex}$	145.98 ± 1.74	194.19 ± 3.10	.004*
ANG_{Rot}	201.14 ± 3.31	263.04 ± 4.39	.004*

Values expressed as mean ± SD. *significance pretest to post-test difference. Abbreviation: DMA, dynamic motion analysis score; LIN_{UD}, up and down translational movements; LIN_{Lat}, side to side translational movements; LIN_{AP}, anterior/posterior translational movements; $ANG_{Flex/Ext}$, flexion/extension rotational movements; $ANG_{LatFlex}$, lateral flexion rotational movements; ANG_{Rot}, core rotational movement. All values expressed in inches.

Table 5 Comparison of FES and FROP-com across training groups

	SBEP		Tai Chi		Wii Fit	
	Pretest	Post-test	Pretest	Post-test	Pretest	Post-test
FES	12.0 ± 2.6	11.0 ± 1.4	10.9 ± 2.1	11.2 ± 2.1	14.1 ± 10.2	11.3 ± 2.8
FROP-Com	5.5 ± 3.1	5.3 ± 2.1	5.6±3.5	5.9 ± 3.5	5.6 ± 3.2	7.3 ± 4.6

Values expressed as mean ± SD. Abbreviations: SBEP, standard balance exercise program; Wii, Wii Fit balance program; FES, Falls Efficacy Scale; FROP-Com, Falls Risk for Older People—Community Setting assessment tool

FIGURES

Figure 1. Pretest and post-test values (Mean±SD) of the center of pressure area in cm (COP_{area}) for the entire sample. *significantly different than pretest values (*P*=.0001).

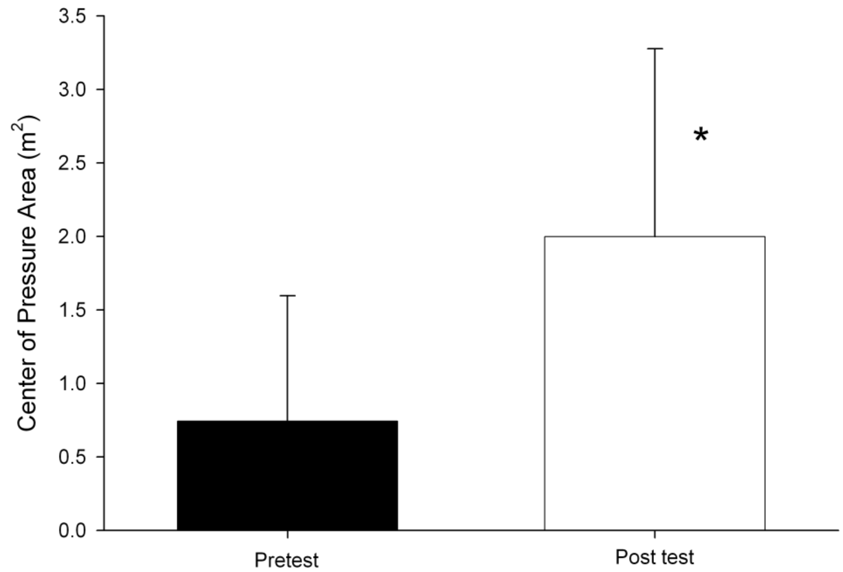

Figure 2. Pretest and post-test values (Mean±SD) of the overall linear displacement in inches (DMA) for the entire sample. *significantly different than pretest values (*P*=.036).