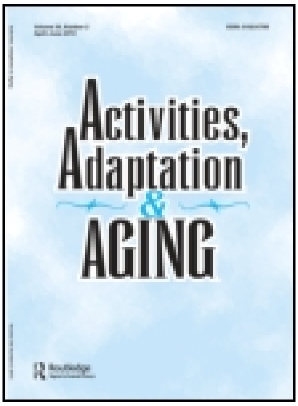

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The Effects of a 15-Week Exercise Intervention on Fitness and Postural Control in Older Adults

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Falls are the leading cause of nonfatal injuries in older adults and often lead to adverse changes in confidence and lifestyle that trigger further declines in postural control. Decreased fitness is associated with poor performance on postural control assessments, especially those that increase task difficulty. The purpose of this study was to analyze the impact of a traditional group fitness class and a Wii fitness exercise program on individual's ability to maintain postural control with an environmental distracter. Eighty-seven community-dwelling seniors were randomized into one of three groups (Control, Wii Fitness, Group Fitness). Interventions were delivered three times per week for 15 weeks. A significant improvement in the Sensory Organization Test (SOT) equilibrium score was seen over time. There was a significant training group by time interaction for 6-minute walk ($p =$ 0.14, effect size = .776). There was a significant pretest (7.2 ± 1.4) post-test (6.7 ± 1.4) comparison for 8-foot Timed "Up and Go" ($p = 0.017$). There was a significant interaction between training groups and time ($p = 0.010$) for chair stands. Post hoc tests revealed that equilibrium scores during cognitive distraction (38.1 ± 20.9) were significantly less than both the visual distraction (51.9 ± 20.2) and auditory distraction (49.3 ± 21.1). There were no differences during the increased environmental load testing ($p = 0.686$). Results indicated that both intervention programs were successful at improving postural control and fitness.

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Falls are the most common cause of nonfatal injuries and hospital admissions for trauma each year and are the leading cause of accidental death in adults older than age 65 (Centers for Disease Control and Prevention [CDC], 2010). In addition, more than a third of adults age 65 and older will fall once or more each year (CDC, 2010). Nonfatal falls often lead to injury, decreased activity, decreased confidence, altered lifestyle, and decreased quality of life (Miller et al., 2009). These lifestyle changes of attitude and activity appear to trigger a cyclical decline in postural control, resulting in an increased prevalence of falls (Wilson et al., 2005).

Postural control is the summation of numerous physiological factors acting together in order to maintain upright posture and balance (Horak, 2006). Variables involved in maintaining postural control can be categorized as either extrinsic (environmental) or intrinsic (personal) factors (Ashley, Gryfe, & Amies, 1977; Nickens, 1985; Silsupadol, Siu, Shumway-Cook, & Woollacott, 2006). Examples of extrinsic factors include poor lighting, slippery surfaces, inappropriately placed furniture, or unfit footwear. Conversely, examples of intrinsic factors include poor balance, sensory deterioration, neurological disorders, or muscle deterioration (Nelson & Amin, 1990; Silsupadol et al., 2006). Extrinsic factors can be avoided and controlled; however, intrinsic factors are directly impacted by the effects of aging (Horak, 2006). Degeneration of vestibular, visual, and somatosensory function in conjunction with decreased sensorimotor processing (decreased cognition), adversely affects older adult's ability to maintain postural control, and all factors steadily decline after age 65 (Laughton, Slavin, & Katdare, 2002; Serrador, Lipsitz, Gopalakrishnan, Black, & Wood, 2009). This, in addition to the increased prevalence of neural disease, decreased neural processing, and decreased muscle strength in older adults, all work to inhibit postural control in this population (Horak, 2006; Horak, Shupert, & Mirka, 1989). Other sensory changes that contribute to disequilibrium include decreased number of cochlear hair cells (decreased prorioception) and decreased neural innervation of the vestibular region (fewer nerve signals being fired), which result in reduced vestibular reactivity and excitability (Bergstrom, 1973; Rauch et al., 2001; Rosenhall, 1973; Rosenhall & Rubin, 1975; Serrador et al., 2009).

A large continuous influx of postural information must be processed before a reaction may occur; the amount of cognitive processing required is dependent on the complexity of the postural task and on the capabilities of the individual's postural control system (Bock & Beurskens, 2011; Horak, 2006). Increased cognitive processing comes with increased task difficulty (Bock & Beurskens, 2011; Teasdale & Simoneau, 2001). Thus, reaction time increases and performance decreases with increasing difficulty of postural task (Bock & Beurskens, 2011; Teasdale & Simoneau, 2001). The control of posture and other processes requiring cognitive function share cognitive resources; as a result, postural performance declines with the addition of a secondary cognitive task (Bock & Beurskens, 2011; Teasdale & Simoneau, 2001). This explains why multitasking may be more difficult for individuals with decreased cognition. Cognitive abilities steadily decline with age in older adults (Bock & Beurskens, 2011; Persson et al., 2006). This decreased cognitive capacity of older adults presents a large challenge to maintaining postural control in this population (Bock & Beurskens, 2011; Teasdale & Simoneau, 2001). Previous work has demonstrated that exercise interventions can be effective at decreasing postural sway in older adults (Bird et al., 2011; Judge, Lindsey, & Underwood, 1993). However, exploration of interventions that increase one's capacity to maintain postural control while performing a secondary cognitive task has yet to be fully elucidated. Therefore, the purpose of this study was to analyze the impact of a traditional group fitness class and a Wii fitness exercise program on individual's ability to maintain postural control while performing a secondary cognitive task.

METHODS

Participants

Participants consisted of 29 males and 58 females with an average age of 75. Participants were excluded if they had a previous history of peripheral or vestibular abnormalities, or if they had experienced two or more documented falls in the previous six months. Additionally, participants were excluded if they were unable to walk without assistance. Prior to data collection, participants completed a senior fitness evaluation and a NeuroCom Sensory Organization Test (SOT).

Instrumentation

The SOT on the NeuroCom Equitest System (NeuroCom International, Clackamas, OR) provides information regarding the use of sensory input or a combination of inputs to maintain postural stability. This system utilizes a force platform and measures vertical reaction forces that are generated from the participants' center of pressure movement from a fixed base of support and transducers embedded in the force platform (Persson et al., 2006). The SOT is used to assess balance abilities and limitations in a wide variety of populations by determining how individuals are able to respond and adapt to a variety of sensory manipulations. This system has the ability to detect the individual's center of gravity (COG) and how far the individual sways from that center. Once the system detects the amount the individual is swaying in one direction, it will respond accordingly with an equal amount of sway from the support surface (ground) or the visual surround (walls). This ability to adjust to the individual's sway is called "sway referencing." Inaccurate information is delivered to the eyes, feet, and joints through sway referencing of the visual surround and support surface (Orr, 2010). This alteration disrupts the available sensory information and allows the tester to evaluate the individual's use of their sensory modalities, which provide afferent information to maintain postural control (Young, 2010). The SOT determines how an individual reacts to constant or changing information from the sway-referenced senses. For example, in Condition 1, vestibular, vision, and somatosensory information is accurate, while in Condition 6, only vestibular information is accurate.

Procedures

Participants were assessed on the SOT and strategy analysis under six conditions with a NeuroCom SOT. The SOT has demonstrated to be a valid indicator of dynamic posturography and is extensively used in clinical and research settings (Judge et al., 1993; Laughton et al., 2002; Suzuki, Kim, Yoshida, & Ishizaki, 2004). This study was approved by the institutional review board. The procedures and protocols were explained and a signed informed consent form was obtained.

The SOT protocol objectively identifies abnormalities in the participant's use of the three sensory systems that contribute to postural control: somatosensory, visual, and vestibular. During the assessment, inaccurate information is delivered to the participant's eyes, feet, and joints through "sway referencing" of the visual surround and/or the support surface. Each participant was fitted with a padded harness attached to the device's framework in order to protect him or her from a fall. Each condition was performed three times. Outcome measures for this test include: (1) Equilibrium score, which quantifies the COG sway or postural stability; (2) sensory analysis ratios, which are used in conjunction with the individual equilibrium scores to identify impairments of individual sensory systems; (3) strategy analysis, which quantifies the relative amount of movement about the ankles (ankle strategy) and about the hips (hip strategy) the participant used to maintain balance during each trial; and (4) COG alignment, which is a plot of the participant's COG position at the start of each trial of the SOT such that each mark indicates COG alignment during a single SOT trial relative to the center of the base of support. Condition 6 was chosen for additional testing of environmental and cognitive loads due to the increased integration needed to combine vision, somatosensory, and vestibular systems. For these reasons, we felt this condition would be the most sensitive assessment of postural control. Additional testing included visual, auditory, and cognitive distracters. These additional distracters functioned as differed attention testing. The visual distracter chosen for this study was a first-person roller coaster simulation (Ravineflyer2, 2008). This was chosen because it did not provide a fixed horizon for the participant to focus on during testing. For the auditory distracters we used audio of crowded streets to more readily simulate public places (Metroopensdoors, 2009). Cognitive load testing included a Stroop test. The Stroop Task is a psychological test of cognitive and attentional capacity (Young, 2010). This test is effective due to one's ability to read words more quickly and automatically than one can name colors (Young, 2010). That is, if a word is printed or displayed in a color different from the color it actually names—for example, if the word "blue" is written in red ink—one will say the word "blue" more readily than they can name the color in which it is displayed, which in this case is red (Young, 2010). Participants are asked to respond with the color they see, and inhibit or disregard the word they read.

Scoring

During the SOT, participants were tested under six conditions, three trials per condition, for a total of 18 trials. Each trial lasted 20 seconds. The support surface (force plate) and walls (visual surround) moved in response to participants' COG (estimated) sway. The overall composite equilibrium score provides a representative score of individuals' ability to maintain postural stability during all conditions (Laughton et al., 2002). Effective use of individuals' sensory inputs is determined from the overall pattern of scores on each of the six conditions. The composite equilibrium score is the weighted average of all scores including Condition 1 average scores, Condition 2 average scores, and three equilibrium scores from each of the trials in Conditions 3–6. The equilibrium scores from each trial are a representation of nondimensional percentage compared to the peak amplitude of A/P sway to the theoretical Anterior/Posterior (A/P) limit of stability (Persson et al., 2006).

The strategy analysis score quantifies the amount of movement of either the ankles or the hips by plotting the information from the force plate and equilibrium scores together (Orr, 2010). The strategy score demonstrates the amount of movement about the ankles (ankle dominant strategy) and hips (hip dominant strategy) that are used to maintain postural stability during each trial. The closer the score is to 0 the more movement/adjustments the individual has made with their hips to maintain stability; likewise, the closer to 100 represents ankle adjustments in order to maintain postural stability. Scores between 0 and 100 represent a combination of the two strategies (Orr, 2010). The most typical strategy dictates that as stability is maintained individuals will utilize primarily an ankle strategy and shift to hip strategy when balance becomes more difficult (Orr, 2010). The minor adjustments utilized during ankle strategy are more desirable because they result in less vertical force, while a shift toward hip strategy occurs as a result of greater instability.

Intervention

Eighty-seven participants were randomized into a Group Fitness (n = 40) and Wii Fitness (n = 29) exercise intervention group. No exercise was prescribed to the control group (n = 18). The Wii exercise group performed exercises three times per week, 45 minutes per day, using a Wii-balance board and weighted vests. The intervention included 15–25 chair stands while wearing the weight vest and bouts of walking for 5–10 minutes at a time. The weight of the vest began at two pounds and was increased two additional pounds every two weeks until it reached the maximum of 10 pounds. Participants were only allowed to wear the vest while playing the Wii Bowling or Wii Boxing games. The Wii Fit Plus balance board was also integrated into the program. Games played were focused on balance and body weight shifting. Participants did not wear the weighted vest while on the balance board. Every participant using the Wii balance board wore a gait belt so that assistants could support them through the ensuing challenges to postural control. The Group Fitness group also performed exercises three times per week, 45 minutes per day. The exercises were based on various traditional senior fitness programs, including a rigorous seated aerobics program. All exercises were led by a certified fitness professional, with participants either seated or utilizing chairs for support. The Group Fitness exercise program was a progressively increasing intensity routine, with exercises aimed at increasing lower leg strength, upper body strength, and flexibility. Some lower leg strengthening exercises included chair stands and chair lunges, while some upper body exercises included triceps extensions and shoulder presses using a medium-strength theraband (Hygenic Cooperation, Akron, OH). Each session included three bouts of walking for 5–10 minutes at a time and ended with 10–15 minutes of stretching.

Data Analysis

SPSS version 18.0 statistical software was used to conduct all data analysis. Analysis included descriptive summaries and a one-way analysis of variance (ANOVA). A composite score was compiled across all conditions and group comparisons were analyzed with a one-way ANOVA to determine if there were differences between groups. Outcome measures included a SOT composite equilibrium score, derived from the strategy analysis for each condition.

RESULTS

Data from the SOT scores are included in Table 1. There was no divided attention condition by training group by time interaction ($p = 0.579$) for SOT equilibrium. There were no divided attention by group ($p = 0.599$), divided attention condition by time ($p = 0.160$), or time by group ($p = 0.578$) interactions for SOT equilibrium. There was a significant improvement in the SOT equilibrium score over time ($p = 0.007$), the pretest SOT equilibrium was 38.8 ± 25.0 and the post-test score was 51.1 ± 17.2. There was a significant difference in SOT equilibrium scores between the divided attention conditions ($p = 0.000$). Post hoc tests revealed that equilibrium while performing the Stroop (38.1 ± 20.9) was significantly less than both the visual distracter (51.9 ± 20.2) and auditory distracter (49.3 ± 21.1). There were no differences between the groups across all increased environmental load testing ($p = 0.686$).

Strategy scores across groups and time are included in Table 2. There was no divided attention condition by training group by time interaction ($p = 0.699$) for SOT strategy. There were no time by training group ($p = 0.862$), divided attention condition by training group ($p = 0.959$), or divided attention condition by time ($p = 0.072$) interactions for SOT strategy. There were no differences between training groups ($p = 0.491$). There was a significant difference between the pretest SOT strategy (54.2 ± 20.8) and post-test SOT strategy (62.8 ± 11.4) scores ($p = 0.012$, effect size = .745). There was a significant difference in the SOT strategy employed between the environmental loading conditions ($p = 0.009$). The SOT strategy was 63.5 ± 13.2 in the no distraction condition, 53.6 ± 18.6 in the Stroop condition, 58.0 ± 17.7 in the visual Divided Attention (DA) condition, and 58.9 ± 18.2 auditory DA condition. Post hoc tests revealed that no distraction (control) was significantly different from the Stroop condition.

Data from the senior fitness scores are included in Table 3. There was a significant training group by time interaction for the 6-minute walk ($p = 0.14$, effect size = .776). The post hoc test revealed that the control group pretest (578.2 ± 121.8) was significantly different from the control group post-test (448.0 ± 268.0). There were no pre–post differences ($p = 0.455$) or training group differences ($p = 0.705$) for the 6-minute walk (Figure 1). There was a significant pretest (7.2 ± 1.4)–post-test (6.7 ± 1.4) comparison for the 8-foot Timed "Up and Go" ($p = 0.017$). There was no interaction between training group and time ($p = 0.246$) or differences between training groups ($p = 0.227$) for the 8-foot Timed "Up and Go" (Figure 2).

There was a significant interaction between training groups and time ($p = 0.010$) for chair stands (Figure 3). The Wii Fitness training group performed significantly more chair stands on the post-test (14.4 ± 5.2) when compared to the pretest (10.0 ± 4.2), and the Group Fitness training group also performed significantly more chair stands on the post-test (14.1 ± 5.4) when compared to the pretest (10.4 ± 4.4). There was a significant time effect for chair stands ($p = 0.004$) and there were no differences between the training groups ($p = 0.320$).

There were no differences in grip strength for training group by time ($p = 0.411$), time ($p = 0.423$), or training groups ($p = 0.774$). There was

TABLE 1 Mean ± SD SOT Equilibrium Scores by Training Group, Divided Attention Condition, and Time

	Wii Fitness		Group Fitness		Control		
Divided Attention Condition	Pretest	Post-test	Pretest	Post-test	Pretest	Post-test	DA Condition Means
Control	24.8 ± 25.1	51.2 ± 23.6	32.6 ± 23.3	46.7 ± 13.1	36.5 ± 32.5	50.2 ± 19.7	40.3 ± 20.9[a]
Stroop	25.9 ± 20.0	38.1 ± 23.8	31.3 ± 23.2	44.2 ± 19.3	47.7 ± 19.9	41.9 ± 12.5	38.1 ± 20.9[b]
Visual	41.7 ± 28.6	61.0 ± 12.1	36.9 ± 26.0	55.8 ± 15.6	55.5 ± 25.7	60.8 ± 9.2	51.9 ± 20.2
Auditory	41.4 ± 28.5	49.7 ± 27.8	39.2 ± 24.5	53.6 ± 19.3	52.0 ± 25.5	60.1 ± 9.5	49.3 ± 21.1
Time Main Effect		Pretest	Post-test				
		38.8 ± 25.0	51.1 ± 17.2[c]				

[a]Main effect for divided attention condition Control (no distraction), was different from Visual and Auditory. [b]Main effect for divided attention condition, Stroop, was different from Visual and Auditory. [c]Time main effect, pretest different from post-test ($p \leq 0.05$).

TABLE 2 Mean ± *SD* SOT Strategy Scores by Training Group, Divided Attention Condition, and Time

	Wii Fitness		Group Fitness		Control		
Divided Attention Condition	Pretest	Post-test	Pretest	Post-test	Pretest	Post-test	Condition Means
Control	62.1 ± 5.5	64.1 ± 11.2	62.6 ± 14.0	57.9 ± 14.0	65.3 ± 17.0	68.9 ± 19.1	62.9 ± 12.1[a]
Stroop	49.0 ± 26.8	53.9 ± 14.7	44.4 ± 20.4	56.4 ± 14.3	55.1 ± 24.8	62.9 ± 11.9	47.7 ± 22.4
Visual	47.1 ± 25.6	63.3 ± 8.7	55.1 ± 24.8	62.7 ± 8.9	62.7 ± 14.5	65.3 ± 17.8	49.8 ± 24.4
Auditory	48.1 ± 27.0	66.4 ± 9.9	45.1 ± 30.1	60.8 ± 9.0	61.7 ± 23.3	71.3 ± 11.8	48.9 ± 27.7
Time Main Effect		Pretest	Post-test				
		54.2 ± 20.8	62.8 ± 11.4[b]				

[a]Main effect for divided attention condition Control (no distraction) was different Stroop. [b]Time main effect, pretest different from post-test ($p \leq 0.05$).

TABLE 3 Mean ± *SD* for Senior Fitness Measures by Training Group and Time

	Wii Fitness		Group Fitness		Control	
Variable	Pretest	Post-test	Pretest	Post-test	Pretest	Post-test
6-minute walk (yds.)	505.3 ± 111.5	555.9 ± 88.6	455.0 ± 171.8	483.3 ± 183.4	578.2 ± 121.8	448.0 ± 268.0[a]
8-foot "Up and Go" (sec.)	8.0 ± 1.5	7.1 ± 1.2	7.4 ± 1.4	6.8 ± 1.0	6.3 ± 1.2	6.2 ± 2.0[b]
Chair stands (no.)	10.0 ± 2.3	14.4 ± 3.0[c]	10.4 ± 4.1	14.1 ± 5.9[‡]	16.4 ± 6.1	15.0 ± 5.7
Grip strength (kg)	23.4 ± 8.6	24.7 ± 7.7	25.9 ± 8.6	25.4 ± 9.8	27.3 ± 6.1	28.2 ± 9.0
Curls (no.)	14.7 ± 3.1	16.9 ± 3.2	16.5 ± 4.4	19.2 ± 3.8	18.6 ± 2.2	19.8 ± 3.9[d]
Shoulder stretch (in.)	5.3 ± 5.0	5.2 ± 7.3	5.4 ± 3.3	5.1 ± 3.4	8.0 ± 6.9	7.6 ± 7.1
Sit-and-reach (in.)	−0.4 ± 2.5	−1.8 ± 2.8	0.5 ± 2.8	0.4 ± 2.2	−0.5 ± 1.6	−0.6 ± 2.4
Body mass index	28.0 ± 4.7	27.5 ± 5.2	26.6 ± 6.2	26.4 ± 5.7	29.4 ± 1.4	29.0 ± 1.9

[a]Control group pretest significantly different from Control group post-test for 6-minute walk. [b]Pretest 8-foot "Up and Go" significantly different from post-test. [c]Wii Fitness pretest significantly different from post-test and Group Fitness pretest significantly different from post-test on chair stands. [c]pretest curls significantly different from post-test curls ($p \leq 0.05$).

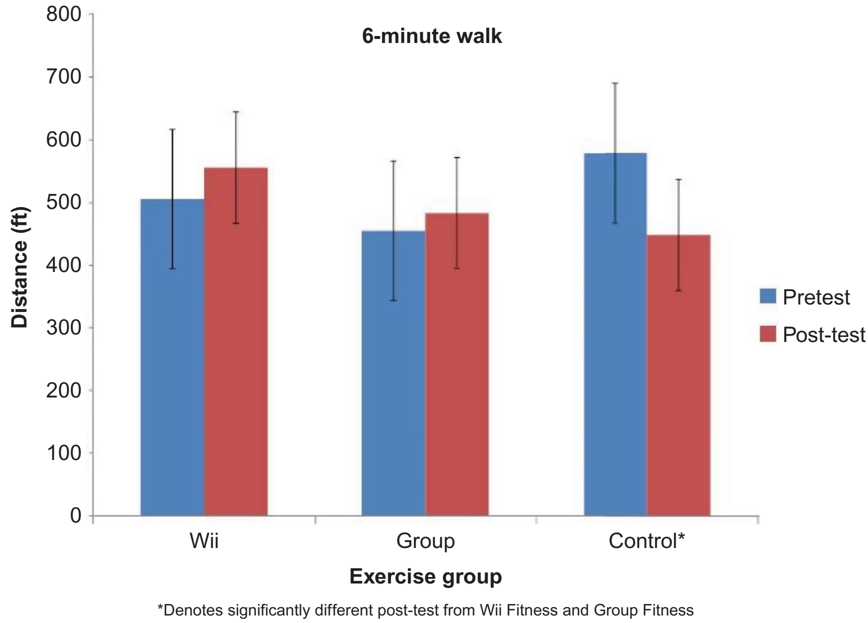

FIGURE 1 Six-minute walk by training group and time (color figure available online).

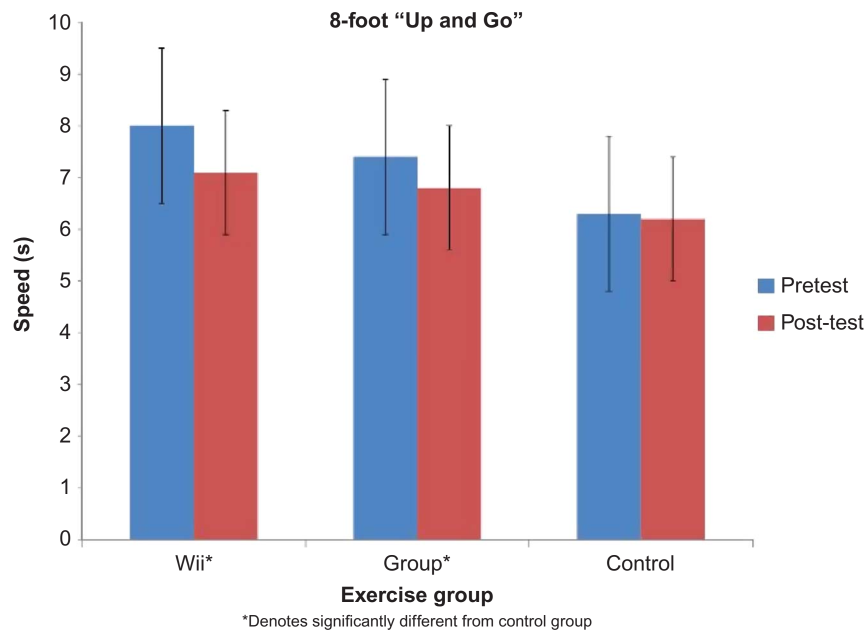

FIGURE 2 Eight foot “Up and Go” by training group and time (color figure available online).

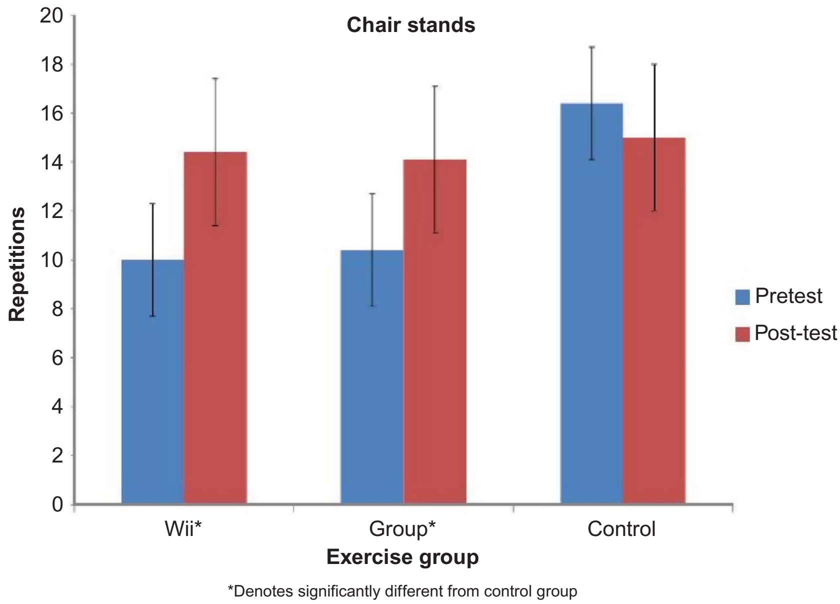

FIGURE 3 Chair stands by training group and time (color figure available online).

a significant difference between pretest (16.6 ± 3.9) and post-test curls (18.6 ± 3.8) ($p = 0.022$). There was no training group by time interaction ($p = 0.748$) or between differences between groups ($p = 0.188$) for curls. There was no training group by time interaction ($p = 0.984$) differences between pretest and post-test ($p = 0.729$) or differences between training groups ($p = 0.599$) for shoulder stretch. There was no training group by time interaction ($p = 0.878$), differences between pretest and post-test ($p = 0.278$) or differences between training groups ($p = 0.618$) for body mass index.

DISCUSSION

As the population ages, the number of fallers is expected to increase. The evidence presented in this study supports the notion that differed attention has a negative effect on postural control and senior fitness. Improvements in balance, lower-limb strength, and gait may ultimately yield reductions in physical disability and falls. These key improvements can help mitigate the natural adverse declines in ability inherent in the aging process, thereby conferring greater independence and enhanced quality of life to older adults. The inclusion of unique exercise interventions that target older adults may improve postural control and an individual's overall health and physical function. Based on these findings, it is evident that older adults have more difficulty maintaining postural control with a cognitive task than in environments with visual or auditory distracters. This information may be used to predict situations in which older adults may be more susceptible to experiencing a fall event. Furthermore, this data documents the ability to make improvements in differed attention postural control and fitness scores with the adoption of frequent exercise training. Although the evidence from this study did not identify a specific mode of exercise, it showed increases for both Group Fitness and Wii Fitness exercise groups. These findings indicate that while declines in postural control and fitness are expected with ageing, the addition of regular exercise can improve postural control, even with environmental distracters and fitness measures. More specifically, it appears that improvements in lower-limb strength are one of the most amendable components in fitness in older adults; this was seen in improvements in repetitions of chair stands and the 8-foot Timed "Up and Go." Improvements in the 8-foot "Up and Go" may speak to increases in dynamic balance, which may be a result of increased lower-leg strength as a result of the exercise interventions. It is also plausible that cardiovascular fitness is one of the first measures to decline and, therefore, must be regularly maintained through regular walking in this population. This was seen in the current study with the decrease in feet walked in the control group. In the absence of an appropriate exercise intervention, these findings may be used by administrators and fitness professionals to progressively expose individuals to dual tasking challenges. According to these findings cognitive tasks are most challenging; therefore, one might start postural-control-challenged individuals with visual and auditory distractions to postural control until they are ready for simple and then more difficult cognitive tasks during postural control.

CONCLUSION

Older individuals have a diminished capacity to coordinate and process environmental distracters while maintaining postural stability. They are also required to employ more hip strategy to maintain balance in more challenging conditions. This decrease in postural stability during static conditions is concerning and could account for the increased incidence in falls within this population. Training programs should be studied for their effectiveness in physiotherapeutically increasing postural control in older individuals during differed attention conditions, thereby reducing the susceptibility for falls within this population. Specifically, this study showed that postural control is most compromised while performing a cognitive task, and that cognitive and postural dual tasking is more amendable than visual and auditory dual tasking. Data from this study indicate that engagement in physical activity programs do increase postural stability and senior fitness scores. Additionally, it can be surmised that physical activity programs maintain fitness levels, thus preventing decreases in function and ability. This finding is important and can be used as justification for the development of exercise interventions to decrease fall risk in community-based programs that serve older adults. Future research should focus on dynamic conditions and situations that further complicate attention to postural control by increasing processing demands by exploring the impact in conjunction with cognitive tasks and determining if this further exposes older adults to falls. Determining the physical and cognitive contributions to postural stability is vital to both understanding postural control challenges and deriving components of future interventions aimed at reducing postural instability.

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