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Research Article

Physical and Cognitive Evaluation of a Neuroplasticity Exercise Program: A Pilot Study

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Abstract

The number of individuals with Alzheimer's disease or related dementias is anticipated to double in the United States by the year 2060 which makes dementia a significant health concern (Center for Disease Control and Prevention, 2018). The purpose of this study was to evaluate the physical and cognitive benefits of a group exercise program, Ageless Grace, in an older population. Seventeen male (n=5) and female (n=12) subjects (66.8+6.5 years) participated in the nine-week program. The primary outcome measures were performed prior to and immediately following the intervention and included physical and cognitive measures. Significant improvements were found for the Patient-Specific Functional Scale (p=0.007); Short Physical Performance Battery (p=0.006); 8' Up and Go (p=0.021); Sensory Organization Test (p=0.001); Naming (p=0.013); Abstraction (p=0.004); and Digit Forward (p=0.035) tests following the intervention. It appears that Ageless Grace is an effective exercise program for improving physical and cognitive function in older adults.

Keywords: Aging; Cognition; Dementia; Neuroplasticity; Seniors

Introduction

Dementia is arguably one of the greatest health concerns among older adults today. Currently, 5.8 million Americans are living with Alzheimer's disease, the sixth leading cause of death in people over the age of 65 [1]. The number of cases worldwide expected to increase from 46.8 million in 2015to 131.5 million in 2050 with an additional 10-20% of older adults expected to be diagnosed with Mild Cognitive Impairment (MCI) [2]. Therefore, preventing cognitive decline has become a public health priority with the World Health Organization (WHO) stressing the importance of governments focusing on preventive services in order to take global action against cognitive decline and dementia [3].

Regular engagement in cognitive and physical activities demonstrates great promise for preventing cognitive decline and dementia. According to recent systematic reviews and expert reports, cognitive training can be effective in improving specific aspects of cognitive function, although the improvements are limited to the cognitive task that is challenged and the extent that these benefits extend to everyday functioning is uncertain [4-6]. Other reviews also indicate that aerobic and resistance exercise training of sufficient frequency and intensity have a significant, and likely synergistic, effect on cognitive function [7-12]. Although discrepancies exist within the literature, the most effective strategy for improvement in cognitive function is likely the simultaneous combination of physical exercise with cognitive challenges in a rich sensorimotor environment as this tends to produce greater results than either cognitive or physical interventions performed separately [13-15].

According to Hötting and Röder [12], physical exercise facilitates neuroplasticity by enhancing neurogenesis, synaptogenesis and angiogenesis which may ultimately result in improved cognitive function. However, Fissler et al., [16] proposed that the facilitation of neuroplasticity might be most prominent either during or right after exercise, suggesting that implementation of simultaneous physical and cognitive interventions might be crucial to achieving significant benefits. There are many activities that have been proposed to target both physical exercise and cognition together. Four examples in the literature that appear to be effective in improving cognition include: Tai Chi, dance, sports activities and exergaming [6,17,18]. In each of these activities the individual is constantly planning, scaling, responding, anticipating, adjusting and coordinating their movements in order to accomplish a task while the brain is fully engaged with the body. In addition, it is hypothesized that novel movement patterns that require motor learning can have similar effects [6] on cognitive function even in the absence of an improvement in cardiorespiratory fitness.

Ageless Grace is a group exercise program for older adults that are designed to improve both physical and cognitive function through playful, imaginative, social and often complex movements. These movements include novel patterns and utilize similar skills as Tai Chi, dance and sports. The class, which is set to music and led by a certified instructor, takes participants through a variety of "tools" (i.e., combined physical and cognitive tasks) which are performed for 3-4 minutes each. Classes typically last 45-60 minutes. The only equipment that is required is a sturdy chair and the ability to play music, making it a cost effective group intervention. An advantage of using Ageless Grace compared to the other interventions is that it is performed seated so that adults of all ability levels may participate and benefit.

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According to the founder of Ageless Grace there are over 2,000 certified instructors around the world. While there have been hundreds of anecdotal reports of participants making significant improvements in both cognition and physical function, the effects of the program have not yet been formally evaluated. Therefore, the primary purpose of this study was to evaluate the short term benefits of the Ageless Grace program on physical and cognitive function in a group of older adults residing in a retirement community. A secondary purpose was to collect data that could be used for the development of a larger randomized controlled trial.

Methods

Study design

The study used a quasi-experimental single group intervention design. The intervention, the Ageless Grace group exercise program, was carried out in the activities room of a local retirement community. All subjects performed the cognitive and field tests in the retirement community building while the computerized dynamic posturography test was conducted in the university research lab.

Settings and participants

Subjects were recruited from a local retirement community through announcements, flyers and a group presentation by the principal investigator. Subject eligibility criteria were as follows: 65-100 years old; non-smoker; independent ambulator in the community without the use of a walker or cane; weight of less than 440 pounds and height of 80 inches; and English speaking. Exclusionary criteria were as follows: blindness, current chemotherapy or radiation treatment; uncontrolled cardiovascular or metabolic condition; peripheral neuropathy; limb amputation; chronic obstructive pulmonary disease; major surgeries within the past 3 months; stage 3 or 4 congestive heart failure; moderate to severe dementia or other serious medical conditions that may prevent participation.

Twenty-six potential subjects responded to the advertisements and were screened (4 did not meet the exclusion criteria; 1 had an unrelated fall after screening and could not complete the initial testing; 4 declined to participate based on interest or schedule). Therefore, 17 male (n=5) and female (n=12) subjects (83.5+4.4 years; range 74-95 years) completed the informed consent process, were approved for and participated in the study, and were included in the final analyses. See table 1 for full details of the study participants. All subjects read and signed a consent form approved by the XXXX Internal Review Board prior to participation. All of the subjects lived in the retirement community. Fall prevalence in the last 12 months ranged from 0 to 6 falls with 14 subjects (82.4%) reporting no falls, 1 subject (5.9%) reporting one fall, 1 subject (5.9%) reporting 4falls and 1 subject (5.9%) reporting 6 falls.

Outcome measures

All outcome measures were administered by trained and experienced investigators, who were not blinded to the purpose of the study. Data collection was initiated following completion of the informed consent process (baseline) and completed within several days following the end of the intervention. The following assessments were performed in a single session in the community room of a local retirement community, except for the Computerized Dynamic Posturography testing which was schedule on a separate day and took place in the Physical Therapy Research Lab at Harding University.

Characteristics	Minimum	Maximum	Mean + SD
Age (years)	74	95	85.5 + 4.4
Height (cm)	149.9	175.3	162.7 + 8.5
Weight (kg)	52.6	88.5	73.5 + 11.6
Falls (no.)	0	6	0.65 +1.69

Table 1: Description of study participants (N=16).

Note: 5 men and 11 women participated in the study

Anthropometrics

Height was measured by a calibrated wall-mounted digital stadiometer (235A Heightronic Digital Scale, Quick Medical Inc., Washington USA). Body weight was measured using a self-calibrating digital scale (Tanita WB-110A, Tanita Corporation, Japan).

Cognitive assessment

Montreal Cognitive Assessment (MoCA)

The MoCA is a valid and reliable measurement of cognitive ability. The test consists of 13 tasks covering 8 areas of cognitive function: Visuospatial/Executive; Naming; Memory; Attention; Language; Abstraction; Delayed recall; and Orientation. The maximum score is 30. The investigator was trained and certified to conduct the MoCA testing [19].

Trail making test

In the Trail Making Test, subjects connect a series of letters and numbers on a paper by drawing lines from one to the next in ascending order as quickly as possible while being timed. There are two versions of this test. Test A uses only letters in ascending order while test B uses both letters and numbers in alternating ascending order. Both versions of the test were used [20].

Digit span test

In the Digit Span Test, subjects were asked to repeat sets of numbers in increasing length, either forwards or backwards, which were stated to them by the researcher. The score reflects the number of correct sequences that the subject was able to correctly repeat back to the researcher [21].

Self-report measures

Activities-specific balance confidence scale (ABC)

The ABC is a16 item questionnaire to assess balance confidence. Participants were asked to rate their confidence in performing a variety of common activities. Confidence is indicated by percentage, with 0% representing no confidence in performing the given activity, and 100% representing total confidence. Total score was the average of the 16 items [22]. The ABC has been found to be reliable and valid in the older adult population [23,24].

Patient Specific Functional Scale (PSFS)

The PSFS is a questionnaire that can be used to quantify activity limitation and measure functional outcome for patients with a variety of conditions and has been found to be reliable and valid in community dwelling older adults [25]. Subjects were asked to identify three to five important activities that they are currently unable to do or are

having difficulty with as a result of their condition. Each activity was scored from 0-10, with 0 representing an inability to perform the activity and 10 representing the ability to perform it as well as before the condition. The final score is the average score of all of the activities combined [26].

Mobility assessment

Short Physical Performance Battery (SPPB)

The SPPB is a group of measures that combines the results of gait speed, chair stand and balance tests [27]. It has been used as a predictive tool for possible disability and can aid in the monitoring of function in older people. The scores range from 0 (worst performance) to 12 (best performance). The SPPB has been found to be reliable and valid in older adults [28-30].

8 Foot Up and Go (8UG)

In the 8UG, participants were asked to stand up from a seated position in a standard arm chair; walk around a cone 8 feet in front of the chair; turn around; walk back to the chair; and sit down again. They are instructed to perform this task "as quickly and as safely as possible". Subjects were allowed to use their hands to push off of their thighs or the arms of the chair and to use an assistive device if they choose. The time it took to complete this task was recorded. Subjects were given one familiarization trial and two performance trials. The best time of the two performance trials was used [31].

Balance testing

Computerized Dynamic Posturography (CDP)

CDP (NeuroCom SMART Balance Master) objectively measures all three sensory systems that affect balance (somatosensory, visual and vestibular) and motor functions in order to identify and quantify impairments in balance abilities and postural reactions. During both of the tests subjects stood in bare feet on a force platform while wearing a secured harness that prevents falling. The two assessments that were utilized were the Sensory Organization Test (SOT) and the Limits of Stability Test (LOS).

The SOT tests the somatosensory, visual, and vestibular systems simultaneously and differentiates the source of balance impairments to one or more of these sensory systems. During the test, the NeuroCom causes distorted information to be given to the sensory systems by utilization of a visual surround which moves in reference to postural sway as well as a support surface which is unstable. Six conditions are tested during the SOT: eyes open, eyes closed, and conflicting visual information on a stable surface, along with eyes open, eyes closed and conflicting visual information on an unstable surface. For the purposes of this study, the composite score, the weighted averages of all of the scores from each of the six conditions, was calculated. The more challenging conditions received higher weighting. A composite score of <38 is associated with an increased risk for falls and an 8-point improvement in the composite score is considered meaningful [32].

The LOS test requires the subjects to intentionally displace their Center Of Mass (COM) toward the 4 cardinal directions and 4 diagonal directions. This test quantifies how far they are able to move their COM in relation to their Base Of Support (BOS). The specific measurements made during LOS testing include: End Point Excursions (EPE): the distance willingly covered by the subject in his very first attempt towards the target, expressed as a percentage; Maximum Excursions (MXE): the amount of distance the subject actually covered or moved his COM; Directional Control (DCL): a comparison between the amount of movement demonstrated in the desired direction (4 cardinal and 4 diagonal directions) to the amount of extraneous movement in other directions.

Intervention

The Ageless Grace exercise class met three times per week for 40-50 minutes over a period of nine weeks for a total of 27 sessions. Each class consisted of performing 12 of the 21 tools (see Appendix A for a list and description of the tools) for approximately 3-4 minutes each depending on the length of the song that was chosen for each tool. A block randomization scheme was used to ensure that each of the tools were utilized equitably throughout the duration of the 27 sessions. The songs were chosen by the instructors and represented a wide variety of styles and genres.

The Ageless Grace tools are intended to be performed in a seated position so the vast majority of movements were performed while seated in a sturdy arm chair. As the participants progressed through the nine-week program several movements were progressed to standing in order to further challenge balance and lower body strength. These movements included: standing on one leg while using the back of the chair for balance; sit to stand transitions; and multi-directional reaching.

Ageless Grace is designed to stimulate six areas of cognition: Strategic Planning; Memory and Recall; Analytical Thinking; Creativity; and Kinesthetic Awareness while also challenging the physiological variables of endurance, strength, power, flexibility, coordination and more. It is intended to be a playful, expressive and emotive approach to movement that engages the heart and mind of the participant just as much as it does the body. Participants are encouraged to perform all of the tools as vigorously and energetically as possible. There were three instructors for the class. The primary instructor is an exercise professional with over 20 years of experience working with older adults. This instructor was trained and certified to deliver the Ageless Grace program. The other two instructors were licensed physical therapists, each with 19 years of experience, who were taught to deliver the Ageless Grace program by the primary instructor but were not certified. The primary instructor delivered 21/27 sessions with the remaining 6 sessions delivered by the other two instructors. In addition to the group exercise sessions, participants were encouraged to perform 10 minutes of Ageless Grace exercise movements on their own on at least 3 additional days. The program is intended to be a daily habit and claims that it can provide benefits to physical and cognitive function when performed as little as 10 minutes per day. Subjects were also instructed to maintain their current level of physical activity outside of the Ageless Grace group and home exercise program. Physical activity levels were not formally assessed.

Statistical Analyses

To retain data from all study participants, we performed an intention-to-treat analysis. Data were collected for 24 different outcomes. Of the 816total data points (17 [number of participants] x 48 [number of pre-tests and post-tests]), only 69 (8.4%) were missing.

Specifically, 33pre-test data points (8.0%) and 36 post-test data points (8.8%) were missing. We considered missing data below 10% as appropriate for multiple imputations. Thus, multiple imputation was used to analyze missing outcomes. Five possible values for each missing outcome were generated by multiple linear regression and the final imputed value was the mean of the five possible values. Multiple imputation was performed with NORM Version 2 for Windows (NORM: multiple imputation of incomplete multivariate data under a normal model; The Methodology Center, Pennsylvania State University, University Park, Pennsylvania).

The Shapiro-Wilk test was used to evaluate normality of data. For data that were normally distributed, a repeated measures analysis of variance (ANOVA) was used to investigate any within-group effects. The Wilcoxon signed rank test was used to assess any within-group effects for non-normally distributed data. Compliance of the participants to the treatment was expressed as the total number of sessions completed by each participant out of the prescribed number of sessions. An alpha level of 0.05 was used for all statistical analyses. Statistical analyses were conducted with IBM SPSS Statistics 24 for Windows (IBM Corp., Armonk, New York, United States).

Results

Seventeen male (n=5) and female (n=12) subjects (mean age = 85.4 years; Standard Deviation [SD] = 4.4; range = 74-96) participated in the study. The group means and standard deviations for weight and height were 73.5 kilograms (SD = 11.1) and 162.7 centimeters (SD = 8.5), respectively. Fourteen subjects reported no falls in the previous 12 months with one subject each reporting 1, 4 or 6 falls respectively. Compliance to group sessions was high, with subjects attending 91% (417/459) of the sessions. However, one married couple accounted for 18 of the 42 absences due to a pre-existing commitment to volunteer at the local hospital one day per week. All other subjects missed four or fewer sessions with three subjects attending all 27 sessions. Compliance to the home sessions was more variable with seven subjects reporting completing them at least three days per week while six subjects reported never or only occasionally completing them. No injuries or falls were observed or reported during testing or training.

The repeated measures ANOVA indicated statistically significant improvements ($p < 0.05$) in SPPB (mean improvement = 1.1; 95% confidence interval [CI] = 0.3, 1.9), 8UG (mean improvement = -1.2 seconds; 95% CI = -2.2, -0.2), and SOT (mean improvement = 11.2; 95% CI = 5.6, 16.8) outcomes. The Wilcoxon signed ranks test showed statistically significant improvements in physical function as measured by the PSFS ($Z = -2.6$, $p = 0.007$) and in the naming ($Z = -2.4$, $p = 0.01$) and abstraction ($Z = -2.9$, $p = 0.004$) domains of cognitive function as evaluated using the MoCA. The Wilcoxon signed ranks test also showed that participants declined in their ability to repeat sets of ascending numbers in increasing length during the Digit Span Test ($Z = -2.1$, $p = 0.03$). No other statistically significant changes in the outcomes were found. Refer to tables 2 and 3 for additional details regarding the statistical findings.

Discussion

The primary purpose of this study was to investigate the short-term benefits of the Ageless Grace program on physical and cognitive function. Statistically significant improvements were found in multiple areas of physical and cognitive function indicating that the program is effective. The secondary purpose of this study was to collect data for a larger randomized controlled trial. The abstraction and naming domains of the MoCA demonstrated significant improvements (p=0.004; p=0.013, respectively) although the composite MoCA score did not (p=0.13). Two recent articles support use of the MoCA to measure the cognitive effects of physical exercise in the elderly and both found positive results [33,34]. Moreira et al., [33] reported significant improvements in MoCA composite score (19.0+2.6 to 22.5+2.3; p=0.01) with a large effect size (0.92) following 16 weeks of a multisensory exercise program with institutionalized older adults. Choi and Lee [34] compared seated ground kayak exercises to a home exercise program in older adults with mild cognitive impairment (<26 on MoCA).

Outcome Measures	Pre-intervention[A]	Post-intervention[A]	Mean Difference[B]	95% Confidence Interval[B]	p[B]
VSE	2.9 (1.2)	3.4 (0.9)	0.4	-0.1, 1.0	0.11
Trail A	45.5 (15.7)	39.6 (13.8)	-5.9	-13.4, 1.5	0.11
Trail B	143.5 (51.0)	147.6 (73.3)	4.0	-20.4, 28.6	0.73
ABCS	71.6 (18.4)	73.1 (16.4)	1.4	-5.5, 8.5	0.66
SPPB	6.5 (2.1)	7.7 (2.6)	1.1	0.3, 1.9	0.006
8UG	10.5 (3.2)	9.3 (2.3)	-1.2	-2.2, -0.2	0.02
DCLB	45.8 (21.0)	51.8 (16.8)	5.9	-6.0, 18.0	0.30
DCLR	62.3 (17.1)	62.6 (18.0)	0.3	-10.8, 11.5	0.95
DCLL	68.9 (7.8)	71.4 (7.1)	2.4	-1.8, 6.7	0.24
DCLC	61.6 (12.1)	58.8 (13.2)	-2.8	-10.0, 4.3	0.41
EPE	46.1 (13.0)	49.1 (12.6)	3.0	-0.4, 6.5	0.08
MXE	60.6 (17.8)	63.1 (16.7)	2.5	-1.2, 6.3	0.17
SOT	53.8 (12.1)	65.1 (13.7)	11.2	5.6, 16.8	0.001

Table 2: Outcomes based on repeated measures ANOVA.

[A]Mean (Standard Deviation); [B]Based on Estimated Marginal Means

Key: VSE -MoCA Visuospatial/Executive; Trail A - Trail Making Test Version A; Trail B - Trail Making Test Version B; ABCS - Activities-Specific Balance Scale; SPPB - Short Physical Performance Battery; 8UG - 8 Foot Up and Go; DCLB - Directional Control Backwards; DCLR - Directional Control Right; DCLL - Directional Control Left; DCLC - Directional Control Composite Score; EPE - End Point Excursion; MXE - Maximal Excursion; SOT - Sensory Organization Test total score

Outcome Measures	Pre-intervention[A]	Post-intervention[A]	Mean Difference[B]	95% Confidence Interval[B]	p[B]
VSE	2.9 (1.2)	3.4 (0.9)	0.4	-0.1, 1.0	0.11
Trail A	45.5 (15.7)	39.6 (13.8)	-5.9	-13.4, 1.5	0.11
Trail B	143.5 (51.0)	147.6 (73.3)	4.0	-20.4, 28.6	0.73
ABCS	71.6 (18.4)	73.1 (16.4)	1.4	-5.5, 8.5	0.66
SPPB	6.5 (2.1)	7.7 (2.6)	1.1	0.3, 1.9	0.006
8UG	10.5 (3.2)	9.3 (2.3)	-1.2	-2.2, -0.2	0.02
DCLB	45.8 (21.0)	51.8 (16.8)	5.9	-6.0, 18.0	0.30
DCLR	62.3 (17.1)	62.6 (18.0)	0.3	-10.8, 11.5	0.95
DCLL	68.9 (7.8)	71.4 (7.1)	2.4	-1.8, 6.7	0.24
DCLC	61.6 (12.1)	58.8 (13.2)	-2.8	-10.0, 4.3	0.41
EPE	46.1 (13.0)	49.1 (12.6)	3.0	-0.4, 6.5	0.08
MXE	60.6 (17.8)	63.1 (16.7)	2.5	-1.2, 6.3	0.17
SOT	53.8 (12.1)	65.1 (13.7)	11.2	5.6, 16.8	0.001

Table 3: Outcomes based on repeated measures ANOVA.

[A]Mean (Standard Deviation); [B]Based on Estimated Marginal Means

Key: VSE -MoCA Visuospatial/Executive; Trail A - Trail Making Test Version A; Trail B - Trail Making Test Version B; ABCS - Activities-Specific Balance Scale; SPPB - Short Physical Performance Battery; 8UG - 8 Foot Up and Go; DCLB - Directional Control Backwards; DCLR - Directional Control Right; DCLL - Directional Control Left; DCLC - Directional Control Composite Score; EPE - End Point Excursion; MXE - Maximal Excursion; SOT - Sensory Organization Test total score

Their findings showed a significant improvement in the composite MoCA score for both groups with the kayak group improving significantly more than the control group ($p<0.003$). The authors noted that the kayak change scores were 5 times higher than the control group (3.46 vs 0.70).

The composite MoCA change score in our study showed a positive upward trend with a mean gain of 1 point but this difference did not meet the level of significance. There are several possible reasons for this lack of improvement. The subject variability in MoCA change scores was high: 8 subjects improved; 4 subjects showed no change; and 4 subjects decreased. In addition, one subject decreased by 5 points and one subject increased by 6 points. The high variability combined with the low subject numbers likely limited our ability to detect significant change for the composite MoCA score. It is unlikely that the short duration of the study was a limiting factor since Choi and Lee [34] found a significant increase of 3.46 points on the MoCA after only 6 weeks of ground kayak training.

The Moreira et al., [33] and Choi and Lee [34] studies did not report changes in any of the MoCA subdomains. In the current study the naming and abstract domains exhibited significant improvement following the intervention. According to a normative data study done by Nasreddine et al., [35] and reported on the MoCA website (www.mocatest.org), the mean score in the naming domain for older adults without cognitive impairmentis 2.88 (SD = 0.36) while the mean score for older adults with mild cognitive impairment is 2.64 (SD = 0.58). Findings from the current study show an improvement from 2.41 (SD = 0.61) at baseline to 2.87 (SD 0.33) after the intervention which makes them similar to older adults without cognitive decline. The same trend is seen with the results of the abstraction domain in this study. Normative data [35]; www.mocatest.org) report a mean score of 1.83 (SD = 0.43) for older adults without cognitive impairment and 1.43 (SD = 0.68) for those with cognitive impairment. In the present study, an increase in abstraction scores from 1.24 (SD = 0.75) to 1.92 (SD = 0.24), makes them similar to older adults without cognitive decline. Based on these findings, it appears that the Ageless Grace program may have improved cognition on the MoCA in these two domains. Although many studies have evaluated and reviewed the impact of combined cognitive and physical intervention on composite MoCA scores [13,14], few assess specifically abstraction within the cognitive component.

Statistically significant improvements were also found for several measures of physical function including PSFS (p=0.007), SPPB (p=0.008), 8UG (p=0.021), and composite SOT (p=0.001). However, these changes may not be indicative of a clinically significant improvement for all measures according to published minimal detectable change values. Previous research has indicated that the minimal detectable change values using the 95% CI (MDC95) for the PSFS, SPPB, and 8UG in older adults are 2.8, 1.9, and 1.6, respectively [25]. Taylor et al., [36] reported that older adults who scored 2.33 to 4.33 on the PSFS were classified as having "severe" loss of physical function and 5.00 to 6.66 as having "moderate" loss of physical function. The mean score of the study participants on the PSFS before receiving the intervention was 4.3 (SD = 1.5) and after the intervention was 6.0 (SD = 2.0) moving them from the "severe" range to the "moderate" range which can be inferred as a clinically important improvement.

SPPB and 8UG both improved significantly following the intervention. SPPB improved by 1.1 points (p=0.006) while 8UG improved by a mean of 1.2 seconds (p=0.021), however, these may not reflect clinically meaningful changes. Reported SEM in community-dwelling older adults for the SPPB range from 0.68-1.42 [37,38]. MDC ranges from 0.54-1.88 [37,39] and an MCID of 1.0 has been reported by one study [39]. For the 8UG the reported MDC ranges from 1.4 [40] to 1.47 [41].

The improvement in SOT scores in this study reveals a significant and likely meaningful change in balance. According to Wrisley [32], a meaningful improvement in normal individuals on the composite SOT score is >8 points. The subjects in this study made an average improvement of 11.3 points. Unfortunately, normative data reported by Nashner [42] only includes individuals up to 70 to 79 years.

The average age of the participants in our study was 85.4, so we were unable to compare our findings to age norms. Interestingly, the normal composite score for the 70 to 79 age group is 64 and our subjects scored 65.1+13.7 post intervention as compared to 53.8+12.1 prior to intervention. Therefore, it appears that these subjects were functioning as well as or slightly better than individuals up to or more than a decade younger than them following the intervention. The significant improvements in the measures of physical function can be considered clinically valuable considering the majority of the Ageless Grace program is performed seated. Other studies have shown that seated exercises can be effective at improving physical function [34,43,44]. Vogler et al., [44] and Liu et al., [43] both compared seated exercise programs to other more upright weight-bearing programs. Choi and Lee [34] reported significant improvements in the Timed Up and Go test ($p < 0.001$) and the functional reach test ($p < 0.001$ following a seated kayak exercise program. Although, in both studies, the weight-bearing programs appeared to be more effective the seated groups made significant improvements in balance from baseline.

Although not measured in this study another component of the Ageless Grace program is endurance. Participants move some part of their body for 40 to 50 minutes in each session. In a systematic review done by Cadore et al., [45], they concluded that a multi-component exercise intervention that includes balance, endurance and strength training is likely the best approach to decreasing falls and improve gait, balance and strength. Ageless Grace could be considered a multi-component program since it includes balance, endurance and, to a lesser degree, strength. There are several limitations to the study which may limit the interpretation of the findings. These include a small sample size, use of residents from a single retirement community, short duration for the intervention and use of a single group design. There are also several strengths to this study which should be noted including a robust assessment strategy, consistent application of the Ageless Grace program and wide variation in subjects' physical and cognitive abilities at baseline. Further research using a randomized design with a larger sample size and longer intervention duration might be more effective in determining the physical and cognitive benefits of Ageless Grace.

Conclusion

We conclude that Ageless Grace appears to be a promising intervention for improving both physical and cognitive function in older adults and should be explored further. The seated nature of the exercise program allows individuals with limited physical function or with chronic disease conditions to participate and potentially benefit from the program. However, individuals that are fully functional and fit may find the physical aspects of the program too easy. The program was not only well tolerated by the participants but they also reported really enjoying it which may lead to better exercise adherence.

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Appendix A: Ageless Grace 21 Tools

Tool	Description
Juicy Joints	Move ankles, knees, hips, wrists, elbows, shoulders, fingers and toes, neck and spine
Dive In!	Simulate swimming and diving strokes such as freestyle, backstroke, breaststroke, butterfly and more
Spelling "B"	Spell words in the air with various parts of the body in many different ways such as using block, cursive, or capital letters
Front Row Orchestra	Pretend to vigorously play various musical instruments while tapping both feet or heels
Zoo-ology	Move like various animals would while making appropriate sounds
Try Chi	Breathe smoothly and steadily while playing with the concepts of slow, deliberate, elegant movements
Yo-Baby	Breathe slowly and use yoga-style movements to stretch the body and use good postural alignment
Body Math	Energetically and quickly play with numbers, beats, patterns and sequences in a variety of movements such as tapping, clapping and snapping
Gentle Geometry	Draw vertical or horizontal lines and shapes in the air with arms, hands, elbows, nose, each knee, thumbs, toes or any part of the body. Try to draw different shapes with different body parts at the same time.
Rockin' Rockettes	Practice kicks of all kinds - singles, doubles, fans, "rockette" kicks - in different directions and at different heights. Wiggle toes and pump ankles.
Spaghetti Spine	Bend the spine gently in all directions - front, back, side to side, and rotate. Move shoulders, rib cage and pelvis.
Express Yourself	Use fingers, arms and hands to "speak" by making dramatic gestures, waving, pointing, shrugging - or anything imaginative.
"Power" Tools	Pretend to use tools for carpentry, gardening, yard work or construction by sawing, digging, hammering, shoveling, chopping, etc.
Saving Face	Use all of the muscles of the neck, cheeks and forehead by making faces, wiggling ears and raising eyebrows.
Balancing Act	Explore moving the center of gravity around over the base of support to stimulate sensory input and challenge postural control.
Breathe Out Loud!	Breathe normally and naturally, big and deep, fast and slow, through the lips and through the nose and in other imaginative ways.
Grab Bag	Grab the air with your hands as if "snatching" things quickly, with agility and in multiple directions.
Shake it up, Baby!	Shake, vibrate, tremor, shimmy - move slowly and then quickly with different parts of the body.
Team Fit	Pretend to play various sports vigorously and imaginatively.
Get Down, Get Up	Bend down to touch the floor, sit up again and reach for the ceiling. Stand up or halfway up and sit back down. Get down on the floor and back up again.
Dance Party!	Vigorously dance in the chair to move in all directions and have fun.

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