Mental Health and Physical Activity 21 (2021) 100410

Contents lists available at ScienceDirect

Mental Health and Physical Activity

journal homepage: www.elsevier.com/locate/menpa

Golf as a physical activity to improve walking speed and cognition in older adults: A non-randomized, pre-post, pilot study

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ARTICLE INFO

Keywords:
Golf
Older adults
Safety
Single- and dual-task walking
Cognitive function

ABSTRACT

The aims of this non-randomized, pre-post, pilot investigation (ClinicalTrials.gov NCT03916887) were to assess: 1) feasibility, safety, and adherence of a 10-week golf program for non-golfer older adults, 2) estimated effects of the program on single- (ST) and dual-task (DT) walking, and cognition, and 3) whether findings support development of a randomized controlled trial (RCT).

Eligible participants included healthy male and female non-golfers, 60–80 years, who could walk independently, swing a golf club, and received medical clearance. The program, conducted at a golf course, focused on improving physical and cognitive function, as opposed to golf performance. ST and DT walking speeds were assessed on a ProtoKinetics Walkway, and cognitive changes using the California Verbal Learning Test II, and NIH Cognitive Toolbox. Of fifteen screened and enrolled participants, fourteen (7F and 7M, 69.5 ± 6.05 yrs) completed the study. One participant sustained a work-related injury and did not complete the study. Average attendance was 94.3%; there were no golf-related adverse events. Estimated increase in physical activity was 25.5% with small Hedges g effect size (ES). Estimated increases in CVLT II composite score (11.2%) and immediate recall (12.6%), and ST (7.2%) and DT (9.1%) walking speeds occurred with medium-large ES. Increases in NIH card sorting (9.3%) and composite (7.3%) scores had small ES's. In an exit survey, participants reported improved physical function, mental and social well-being, and all planned to continue playing golf. ES estimates suggest 50 participants per group will be required to adequately power ($\beta = 0.8$; $p < 0.05$) a future RCT. The study was funded by the Royal & Ancient Golf Association.

1. Introduction

Age-related declines in walking performance, strength, and balance limit functional capacity and are associated with increased fall risk, while cognitive declines affect attention, working memory, and the ability to acquire information and adapt to new situations (Seidler et al., 2010; Williams & Kemper, 2010). Moreover, there is a link between physical and cognitive declines, such as between walking and executive function, because walking requires executive processing, attention and suitable responses to internal and external cues (Amboni, Barone, & Hausdorff, 2013). The ability to simultaneously perform cognitive tasks while walking is important for carrying out activities of daily living; however, walking performance is altered (i.e. speed decreases and gait variability increases), and fall-risk increases, when older adults perform dual-tasks (DT) such as walking while spelling or counting backwards (Al-Yahya et al., 2011; Woollacott & Shumway-Cook, 2002).

One factor known to mitigate both the physical and cognitive effects of aging, is physical activity (PA). For example, improvements in single-task (ST) walking speed of between 0.12 and 0.17 m/s have been reported following yoga, resistance, coordination, and mixed-exercise programs conducted from between 8 and 40 weeks (Hortobágyi et al., 2015; Zettergren, Lubeski, & Viverito, 2011). Additionally, improvements in executive function, episodic memory, working memory, attention and processing speed, have been reported following resistance-, aerobic-, balance-, Tai-Chi- and combined cognitive/activity-training; however, other reports suggest that the effects of PA interventions on improved cognitive abilities in healthy older adults are mixed and require further study (Snowden et al., 2011; Kelly

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https://doi.org/10.1016/j.mhpa.2021.100410
Received 11 May 2021; Accepted 29 May 2021
Available online 2 June 2021

et al., 2014; Law, Barnett, Yau, & Gray, 2014; Erickson et al., 2019). Similarly, systematic review and meta-analysis on the effects of PA on DT walking performance concluded that PA tended to improve DT walking performance, primarily by increasing DT walking speed; however, evidence concerning whether the interventions reduce DT cost or altered dual-task strategy during walking was lacking (Plummer, Zukowski, Giuliani, Hall, & Zurakowski, 2016).

While there are known benefits of PA and exercise, there are many real or perceived barriers for older adults, including discomfort, fear of injury and social isolation (Dunlap & Barry, 1999). Golf is a unique multimodal recreational PA with multiple, simultaneous physical and cognitive challenges as well as the opportunity for social engagement, that might demonstrate greater adherence among older adults than traditional exercise (Fig. 1). Golf play is considered a moderate-intensity physical activity for seniors (Cann, Vandervoort, & Lindsay, 2005) and is associated with improved cardiovascular, respiratory, and metabolic profiles (Murray et al., 2016). Golf requires extensive walking, squatting and bending (e.g. to mark, pick-up and replace the ball), static and dynamic postural control, and high-power swings. Golf is also a cognitively complex, multi-tasking activity that requires participants to estimate distances and select the appropriate club, determine swing speed, navigate changing terrain (hills, sand traps, varying heights of grass), track and find balls, pay attention to other golfers, analyze wind conditions and putting slopes and speed, assess swing and putt performance, and continuously keep score, while following the rules and etiquette of the game. These simultaneous physical and cognitive challenges led us to hypothesize that non-golfing older adults might improve their walking speed and cognitive and DT capabilities following participation in a golf program.

We recently reported that a 12-week golf program for older male military veterans conducted on a VA campus improved chair-stand, 8-foot-up-and-go time, and dynamic postural control (Du Bois et al., 2019, 2021). In the present study we expanded the scope of the previous investigation to address a more diverse cohort (i.e. include non-veterans), be more gender inclusive (i.e. include males & females), be conducted within the local community (i.e. public golf course), and examine the effects on ST and DT walking, and cognition. Thus, the aims of the current study were to: 1) obtain information on the feasibility, safety, and adherence of a 10-week golf program for non-golfing older adults; 2) assess the estimated effects, as quantified using Hedges g effect sizes (ES), of the program on ST walking speed, cognition, and DT capabilities, and 3) follow guidelines from the CONSORT extension for pilot and feasibility trials (Eldridge et al., 2016) and the National Center for Complimentary and Integrative Health's (National Center for Complementary and Integrative Health, 2021) Framework for Developing and Testing Mind and Body Interventions (Center for Complementary and Integrative Health, 2021), to determine if the findings from this non-randomized, pre-post pilot study, warrant an expanded, adequately powered ($\beta = 0.8$; $p < 0.05$), two-arm RCT. We hypothesized that the program would be feasible, safe, and adherent, and that the estimated effects on improvements in ST and DT walking speed, DT walking costs, and measures of cognition would be medium to large.

2. Methods

2.1. Overview

Golf for Healthy Aging (GHA; ClinicalTrials.gov NCT03916887) is a non-randomized, pre-post, pilot study designed to examine the feasibility, safety, and adherence of a 10-week golf program for healthy community-dwelling, male and female non-golfers aged 60–80 years. The study also quantified the effect sizes in changes in ST and DT walking speed, DT costs, and cognitive processing between the pre- and post-measures, and the sample sizes required to develop an adequately powered ($\beta = 0.8$; $p < 0.05$) expanded RCT. Additionally, we assessed the enjoyment of the program utilizing an exit survey and (National Center for Complementary and Integrative Health, 2021) whether there were changes in participants' activity levels.

Baseline testing took place during the week preceding commencement of the golf program and follow-up testing in the week after the end of the program in a biomechanics laboratory at the University of Southern California (USC). The USC Institutional Review Board approved the study, and all participants provided their consent to participate (HS-17-00004).

2.2. Participants: recruitment, screening and enrollment

The study was designed to accommodate a maximum of 15

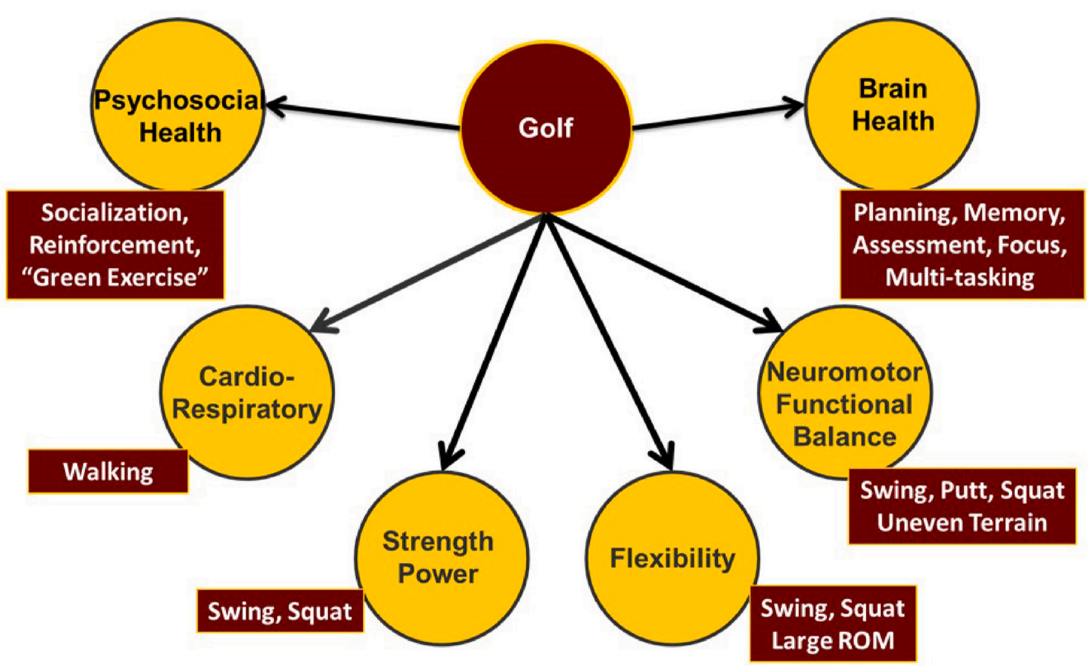

Fig. 1. Golf Framework: Multi-modal, cognitively complex, recreational exercise activity.

participants and was conducted over two academic semesters (9 months) to be adequately staffed with at least one graduate student, the project manager, and the golf instructor in attendance. Recruitment of participants was conducted through flyers placed in retirement communities, senior fitness training locations, USC health care clinics and through word-of-mouth. Participants underwent an initial phone screen to ensure that they met all inclusion criteria and did not have any conditions that would exclude them from the study. Potential participants were required to be either never-golfers or those who had not played any golf during the past 6 months or participated in any golf-related activity more than 3 times in the past 2 years. Additionally, they were required to be between 60 and 80 years of age and receive medical clearance from their primary care physician. Exclusion criteria were any medical or cognitive condition that would affect participants' hearing, comprehension or recall of golf instructions, their ability to walk independently on the golf course, or to swing a golf club.

A total of 36 individuals evinced an interest in participating in the program. Of those, 29 passed the phone screen. Eventually, 7 females and 8 males were eligible, able to acquire medical clearance, and available to attend training during the scheduled days and times (Fig. 1). They were all healthy older adults, ranging in age from 60 to 80 years, and residing in Los Angeles County, and were thus consented and enrolled in the study.

2.3. The golf program

Participants were enrolled in batches of three to four golfers at a time, and each group received twice-weekly golf instruction, for 1.5 h per session, over 10 weeks. Instruction was imparted by a Professional Golf Association (PGA) of America certified golf instructor with more than 25 years of golf teaching experience, at the Monterey Park Golf Course (MPGC) in Monterey Park, CA. MPGC is a public, 9-hole executive course. The program was designed to be as safe and effective as possible for people with no or limited prior experience in the sport.

The program was progressive in nature and included warm-up, driving range, putting, and course activities. As the program progressed, more time was devoted to on course play and less to the other activities (Table 1). Although the instructor assisted the participants so that they were proficient enough to play on the course, the emphasis of the program was on physical activity and exercise, and not golf performance.

The first week of training commenced with 30 min of preliminary warm-up exercises which served to prepare participants for the physical challenges of golf. Examples of these preparatory activities have been published previously (Du Bois et al., 2019). The duration of the warm-up period was decreased progressively from week one to week seven, so that by week seven onwards, only 10 min of warm-up and driving range activities took place. Participants received training in the essential elements of the full-swing and short game at the driving range. On-course play commenced during week four, with two holes of play. During each successive week, the driving range time was reduced, and the number of holes played was increased, until participants could play nine holes independently by week ten.

Table 1
Training program specifics.

Week No.	Activity (same on both days of each week)	Time (min)
1	Dynamic warm up – golf-specific drills and exercises	25
	Driving range, introduction to full swing	65
2	Dynamic warm up – golf-specific drills and exercises	25
	Driving range, full swing and putting	65
3	Dynamic warm up – golf-specific drills and exercises	20
	Driving range, full swing, chipping, pitching	70
4	Dynamic warm up – golf-specific drills and exercises	20
	Driving range	40
	On-course play	30
5	Dynamic warm up – golf-specific drills and exercises	20
	Driving range	25
	On-course play	45
6	Dynamic warm up – golf-specific drills and exercises	15
	Driving range	10
	On-course play	65
7	Dynamic warm up – golf-specific drills and exercises	5
	Driving range	5
	On-course play	80
8	Dynamic warm up – golf-specific drills and exercises	5
	Driving range	5
	On-course play	80
9	Dynamic warm up – golf-specific drills and exercises	5
	Driving range	5
	On-course play	80
10	Dynamic warm up – golf-specific drills and exercises	5
	Driving range	5
	On-course play	80

Note. Holes were truncated as required to complete all activities within 90 min per session. Total distance walked for 9 holes was 1.79 ± 0.37 miles.

2.4. Adherence and safety

Adherence was assessed as: 1) the number of training sessions attended, divided by the total number of sessions offered x 100 (percent attendance) and 2) counting the number of participants that completed the entire training program as well as baseline and follow-up testing.

Safety was evaluated by assessing the number and severity of program-related adverse events.

2.5. Physical activity levels

Participants were asked not to practice any other golf-related activities during the study, to control for the amount of golf played across participants. At the start and completion of the study, all participants were administered the Recent Physical Activity Questionnaire (RPAQ) to assess their physical activity levels. The RPAQ, developed by the Medical Research Council Epidemiology Unit of Cambridge University, assesses physical activity across four domains (at home, during work, during transport, and during leisure time) over the past 4 weeks.

Each activity is ascribed a specific metabolic equivalent (MET), which represents the activity's energy cost as a multiple of resting metabolic rate (Jetté, Sidney, & Blümchen, 1990). The MET used for golf (4.5) was that for 'general golf' (Ainsworth et al., 2000).

2.6. Testing procedures

Single- and Dual-task Walking: Testing took place at the USC Jacquelin Perry Musculoskeletal Biomechanics Research Laboratory. The ProtoKinetics Zeno Walkway (ProtoKinetics, Havertown, PA) was used for all walking tests. It is comprised of a 16-level pressure-sensing pad and provides a variety of spatiotemporal outcome measures. The walkway included 1.5 m acceleration (walk-in) and 1.5 m deceleration (walk-out) distances, which were demarcated by safety cones. Thus, walking speed and spatiotemporal variables were collected over the middle 8 m distance, and were exported directly from the ProtoKinetics software. The ST instructions were to "walk as fast and as safely as possible without running, through the safety cones". For the DT condition, participants were given a unique, randomly generated three digit number between 150 and 350 for each trial, and told to "walk as fast and as safely as possible without running, through the safety cones, while also counting backwards from the assigned number by three". Five trials of single-task (ST) and five trials of dual-task (DT) walking conditions were recorded. The first three successful ST and DT walking trials were used for analysis, and walking speed, stride length, and cadence were averaged across the three trials. During DT walking, no instructions were given regarding which task to prioritize. DT walking speed cost was calculated as (ST performance – DT performance)/ST performance.

Measuring single and dual task (subtraction by 3s) walking speeds in healthy older adults is reliable and have a test-retest ICC of 0.85 and 0.82 respectively (Muhaidat, Kerr, Evans, & Skelton, 2013).

Cognition: Both the National Institutes of Health Toolbox Cognition Battery (NIH–C) and the California Verbal Learning Test 2nd Edition (CVLT-II) were administered in an isolated, quiet room to limit distractions and ensure confidentiality. The NIH–C is an assessment of cognitive function and includes the following subdomains - executive function, episodic memory, language, processing speed, working memory, and attention (Weintraub et al., 2013; Zelazo et al., 2014). A Fluid-Cognition composite T-score ($M = 50$; $SD = 10$), corrected for education, gender, and race/ethnicity is also generated based upon performance across the 5 subdomains. The NIH–C is valid and reliable in healthy older adults and has a test-retest ICC of between 0.48 and 0.92 (Cole, Yen, Dudley-Javoroski, & Shields, 2021).

The CVLT-II is a standardized, norm-referenced, word-recall test that provides a comprehensive assessment of verbal learning and episodic memory (PsychCorp, Pearson, Inc; Woods, Delis, Scott, Kramer, & Holdnack, 2006). Four measures were examined: 1) immediate word recall summed over 5 trials (CVLT-IR), 2) short-delay recall following a 3 min distraction (CVLT-SD), 3) long-delay recall following a 20 min distraction (CVLT-LD), and 4) a composite T-score ($M = 50$, $SD = 10$) based upon performance across the three subdomains. CVLT data were analyzed using the CVLT-II Software package (PsychCorp®). The CVLT-II is valid and reliable in healthy adults 18–88 yrs and has a test-retest ICC of between 0.80 and 0.84 (Woods et al., 2006).

2.7. Qualitative assessment of training program

An exit survey was administered to all participants upon completion of the follow-up laboratory session (Appendix A). Participants were asked open-ended questions to assess how their participation in the 10-week golf training program affected their physical function (such as physical endurance, strength, flexibility, sleep etc.), mental wellbeing (such as stress, anxiety, concentration, memory etc.), and social well-being (such as support, friendship, trust etc.). They were also asked whether they planned to continue to play golf at the end of the training program.

2.8. Statistical analysis

Estimated changes in walking parameters, dual-tasking performance, and cognitive measures were evaluated for their ES using Hedges' g statistic, with 0.2, 0.5, and 0.8 representing small, medium and large ES's, respectively (Lakens, 2013). Sample size (SS) calculations are also reported and reflect the number of participants per group that would be required to develop an adequately powered ($\beta = 0.8$; $p < 0.05$) two-arm RCT with an intervention and a control group. To determine if the pre-post changes were confounded by the participant's baseline health status, a Pearson correlation analysis was conducted between the baseline health measures and the pre-post estimated changes. None of the correlations were significant ($p > 0.05$) and thus there was no need to covary for baseline health status.

3. Results

3.1. Participants: recruitment, screening and enrollment

A total of 36 individuals evinced an interest in participating in the program. Of those, 29 passed the phone screen and 22 of these acquired medical clearance (Fig. 2). The first 15 eligible participants (7 females and 8 males) that were available to attend the scheduled golf program sessions were enrolled in the study and provided their informed consent to participate. They were all healthy older adults, ranging in age from 60 to 80 years, residing in Los Angeles County, and matching the criteria for a lack of golf participation. The mean age of participants who completed the study (7 female and 7 male) was 69.5 ± 6.05 years, mean height 1.67 ± 0.08 m and mean weight at the start of the study was 79.21 ± 17.65 kg. Additional health data is presented in Table 2.

3.2. Adherence and safety

The participants attended 283 out of a possible 300 sessions for an average attendance of 94.3%. All but one participant completed the intervention and pre-post testing. That participant sustained a work injury unrelated to the intervention and had to leave the study on week 8. There were no intervention-related adverse events. All outcome

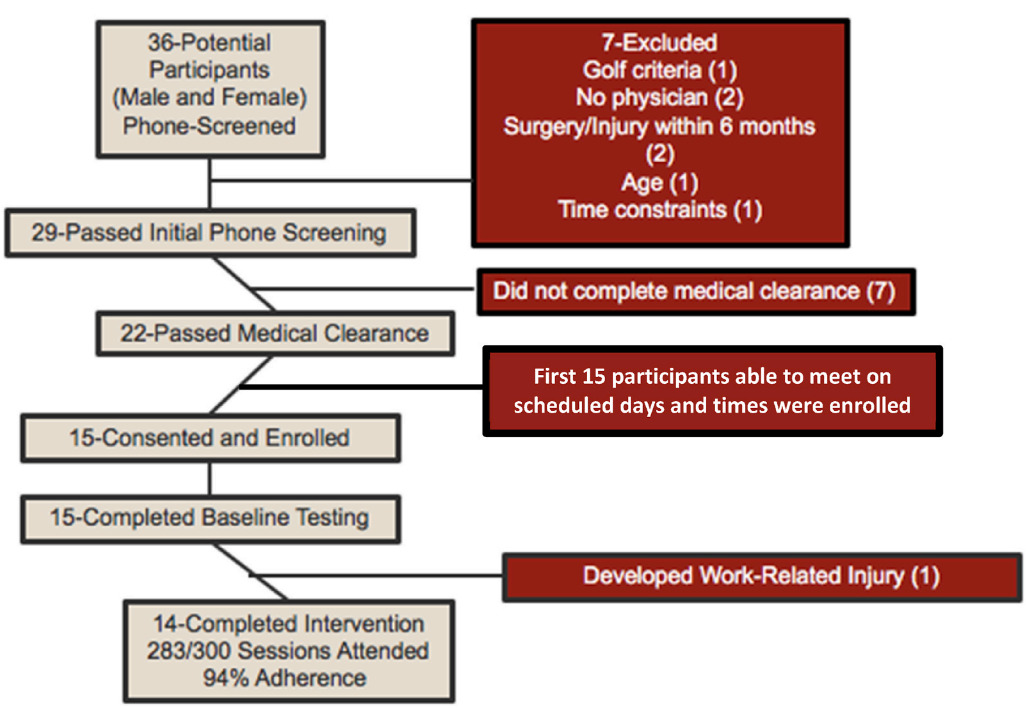

Fig. 2. Recruitment, enrollment and adherence flow chart.

Table 2
Health data.

Variable	Pre (Mean ± SD)	Post (Mean ± SD)	Change (Mean ± SD) (95% CI)
Weight	79.21 ± 17.65	78.33 ± 17.5	0.88 ± 2.49 (−0.56, 2.32)
BMI	28.19 ± 4.69	27.86 ± 4.67	0.33 ± 0.66 (−0.05, 0.71)
RHR	70.61 ± 9.55	68.04 ± 8.66	2.57 ± 3.96 (0.28, 4.86)
BP syst	134.29 ± 14.64	136.54 ± 13.57	2.25 ± 4.58 (−0.40, 4.90)
BP diast	72.82 ± 8.93	74.96 ± 9.00	2.14 ± 5.23 (−0.88, 5.16)

Note. Data reflects the 14 participants (7 male; 7 Female) that completed both the baseline and follow-up testing. Weight in kg, BMI = Body Mass Index in kg/m^2, RHR = Resting heart rate in beats/min, BP = blood pressure in mmHg, syst = systolic, diast = diastolic. CI = 95% confidence interval.

analyses were conducted on the 14 participants that completed the golf program and pre- and post-program assessments.

3.3. Physical activity levels

Estimated physical activity levels (which included the golf-training activities) demonstrated a 25.5% increase between the Pre (2249 ± 1734 MET-minutes per week) and Post (2822 ± 1859 MET-minutes per week) assessments and the ES was 0.30. The average MET-minutes per week for their golfing activities was 1012.

3.4. ST and DT walking speed

Results for ST and DT walking speed, DT walking speed cost, stride length, and cadence estimates are reported in Table 3. Estimated ST walking speed increased by 7.2% and estimated DT walking speed increased by 9.1%, with a medium-large ES. Estimated DT walking speed cost decreased by 20%, however, with a small ES. Estimated ST stride length showed a 4.4% increase and DT stride length a 2.6% increase, both with small ES. Estimated ST cadence demonstrated a 4.4% increase and DT cadence a 5.8% increase, with small and medium ES, respectively.

3.5. Cognition

Results for CVLT II and NIH–C toolbox are reported in Tables 4 and 5 respectively. Estimated CVLT II composite score increased by 11.2% and immediate recall increased by 12.6% with medium-large ES. Estimated CVLT II long delay increased by 10.6% with a small ES. The estimated NIH–C toolbox composite score increased by 7.3%, card sorting performance improved by 9.3%, attention performance increased by 6.4%, working memory by 5.8%, and processing speed by 5.7%, all with small ES.

Table 3
Gait variables.

Variable	Pre (Mean ± SD)	Post (Mean ± SD)	Change (Mean ± SD) (95% CI)	g	SS
ST speed	1.95 ± 0.17	2.09 ± 0.21	0.14 ± 0.20 (0.02, 0.26)	0.70	15
ST stride length	1.56 ± 0.2	1.63 ± 0.15	0.07 ± 0.11 (0.01, 0.13)	0.38	45
ST cadence	148.65 ± 18.04	155.17 ± 15.94	6.52 ± 19.60 (−4.79, 17.83)	0.37	47
DT speed	1.75 ± 0.19	1.91 ± 0.22	0.16 ± 0.19 (0.05, 0.27)	0.75	13
DT stride length	1.56 ± 0.17	1.60 ± 0.17	0.04 ± 0.06 (0.00, 0.08)	0.20	156
DT cadence	136.29 ± 13.81	144.24 ± 15.73	7.95 ± 14.42 (−0.37, 16.27)	0.52	25
Velocity cost	0.10 ± 0.09	0.08 ± 0.09	0.02 ± 0.10 (−0.04, 0.08)	0.22	130

Note. Data reflects the 14 participants (7 male; 7 Female) that completed both the baseline and follow-up testing. ST = single task, DT = dual task. g = Hedges' g, CI = 95% confidence interval. Units: speed in m/s, stride length in m, cadence in steps/min. Sample size (SS) calculations reflect the number of participants per group required to develop an adequately powered (β = 0.8; p < 0.05), two-arm, RCT.

Table 4
California Verbal Learning Test II.

Variable	Pre (Mean ± SD)	Post (Mean ± SD)	Change (Mean ± SD) (95% CI)	g	SS
Comp	59.29 ± 8.89	65.93 ± 6.27	6.64 ± 7.84 (2.11, 11.17)	0.85	11
IR	49.71 ± 8.13	56 ± 8.11	6.29 ± 6.89 (2.31, 10.27)	0.75	13
SDR	10.29 ± 3.17	10.43 ± 2.87	0.14 ± 2.51 (−1.31, 1.59)	0.05	2475
LDR	10.79 ± 2.83	11.93 ± 2.37	1.14 ± 2.45 (−0.27, 2.55)	0.43	415

Note. Data reflects the 14 participants (7 male; 7 Female) that completed both the baseline and follow-up testing. Comp = Composite (T score) IR = immediate recall (number of words), SDR = short delay recall (number of words), LDR = long delay recall (number of words). g = Hedges' g. CI = 95% confidence interval. Sample size (SS) calculations reflect the number of participants per group required to develop an adequately powered (β = 0.8; p < 0.05), two-arm, RCT.

Table 5
National Institutes of Health Toolbox Cognition Battery.

Variable	Pre (Mean ± SD)	Post (Mean ± SD)	Change (Mean ± SD) (95% CI)	g	SS
Composite	51.07 ± 9.96	54.79 ± 8.46	3.72 ± 6.27 (0.10, 7.34)	0.39	43
Attention	46.07 ± 8.02	49.00 ± 9.70	2.93 ± 7.46 (−1.38, 7.24)	0.32	62
Wk memory	53.43 ± 7.28	56.5 ± 11.34	3.07 ± 6.80 (−0.85, 6.99)	0.32	62
Card	50.14 ± 12.41	54.79 ± 11.83	4.65 ± 7.09 (0.56, 8.74)	0.37	47
Proc speed	50.43 ± 12.39	53.29 ± 9.6	2.86 ± 9.91 (−2.86, 8.58)	0.25	101
Seq mem	53.5 ± 9.97	52.21 ± 8.27	1.29 ± 7.99 (−3.33, 5.91)	0.14	317

Note. T-scores for the 14 participants (7 male; 7 Female) that completed both the baseline and follow-up testing. g = Hedges' g., Wk = working, Card = card sorting, Proc = processing, Seq mem = sequential memory. CI = 95% confidence interval. Sample size (SS) calculations reflect the number of participants per group required to develop an adequately powered (β = 0.8; p < 0.05), two-arm, RCT.

3.6. Qualitative assessment of training program

Participant responses to the exit survey are presented in Appendix B. The participants reported improvements in physical function, with seven indicating improvements in endurance, five in strength, nine in flexibility and five in sleep. Mental wellbeing also improved, with 10 participants indicating a reduction in stress and two indicating improved concentration. Finally, with respect to social wellbeing, two stated that they felt increased support and eight indicated increased friendship opportunities. All participants stated that they would continue to play golf after the training program.

4. Discussion

The purpose of this non-randomized, pre-post, pilot study was to investigate the adherence and safety of a 10-week golf training program, as well as its estimated effects on walking parameters, dual-task walking, and cognition in healthy non-golfing older adults. We hypothesized that the program would have high adherence and be safe for the participants, and that estimated improvements in single- and dual-task walking speed and cognitive measures would demonstrate large ES. We adopted these hypotheses because golf play is a cognitively-complex, multimodal, and multitasking activity that includes simultaneous physical, cognitive, and social demands.

The 10-week golf intervention was safe and had high adherence: there were no golf-related adverse events or drop-outs. The adherence rate was 94% with 283/300 total sessions attended, with 14/15 participants being able to complete both the baseline and follow-up testing. The participant that had to leave the study after week 8 sustained a work-related injury. Although adherence to exercise programs for older adults is influenced by program characteristics and personal factors, several systematic reviews corroborate that adherence is generally higher in supervised programs, such as the present study. (River-a-Torres, 2019). Nonetheless, Picorelli and colleagues reported that the proportion of available sessions attended in these programs ranged from 58 to 77% (Picorelli, Pereira, Pereira, Felício, & Sherrington, 2014). Thus, participants in the current study appear to have been especially adherent. One reason might be that participants enjoyed the attention afforded by the 1:4 and 1:3 ratios of PGA instructor to participants, as well as accompanying research staff, as evinced by participant statements such as "Staff were so supportive; feeling very safe and cared for" or "Everyone in my group were like cheer leaders. I met great people on my team."

Recent physical activity, during the four weeks preceding the start of the training program, and during the final four weeks of the program, was assessed with the RPAQ questionnaire, which required participants to provide hours per day and days per week of multiple physical activities across four domains. On average, the percent of the total physical activity attributed to golf participation was 36% during the four weeks prior to follow-up testing, whereas the percentage of participation in other activities decreased by approximately 10% during this same period. Hence, the overall effect of the program was to increase estimated total physical activity by approximately 26%. A meta-analysis (Chase, 2015) assessing a variety of physical activity interventions for older adults indicated an increase in physical activity in the treatment groups compared to controls equivalent to 620 more steps per day or 73 more minutes PA per week, with a Cohen's d ES of 0.18, while the single group pre-post intervention ES was 0.23. Thus, the present study's ES of 0.3 over 10 weeks appears to suggest that the golf program is an adequate means of increasing PA in older adults.

Regarding efficacy, the golf-training program demonstrated medium-large Hedges' g ES for estimated improvements in ST (0.70) and DT (0.75) walking speed, and CVLT II immediate recall (0.75), and composite score (0.85). Sample size calculations for the design of a follow-up two-arm RCT, suggest that the RCT would be adequately powered ($\beta = 0.8$; $p < 0.05$) to detect significant golf-program-related improvements in these outcome measures with a reasonable sample size of 15 participants per group. Small-medium ES were found for estimated increases in ST stride length (0.38) and cadence (0.37), DT cadence (0.52) and NIH Toolbox composite score (0.39) and card sorting ability (0.37). Sample size calculations for the design of a follow-up two-arm RCT suggest that 50 participants per group would be needed to adequately power the study to include these additional outcome measures. All other outcome measures demonstrated small to negligible effect sizes, suggesting that the golf training program is not likely to be effective in changing these parameters and they should not be included in a future RCT.

Golf includes extensive walking over hills and multiple types of terrain, repetitive squatting to tee up, mark, and retrieve the ball, and powerful club swings. Further, participants must walk quickly between golf shots and to the next tee box, to keep pace and prevent other players on the course from having to wait. Thus, we hypothesized that participants would increase their ST walking speed and we are not surprised to find that the estimated increase was associated with a medium-large ES. Participants in the present study demonstrated an average baseline ST walking speed of 1.95 ± 0.17 m/s which is relatively fast compared to normative data (1.59 ± 0.45 m/s) for older adults aged 75.18 ± 8.55 yrs. Consequently, the average estimated increase in ST walking speed, 0.14 m/s, which is consistent with reports from other physical activity interventions (0.11–0.17 m/s) in older adults (Hortobágyi et al., 2015; Zettergren et al., 2011), appears to be especially profound in this high-functioning cohort. Walking speed can increase either by increasing stride length (SL), cadence (CAD), or both. In the present study, estimated change in average ST walking speed (6.9%) was associated with increases in both SL (4.5%) and CAD (4.4%).

Golf also requires simultaneous complex cognitive processing, that includes estimating pin distance and selecting the appropriate club, determine swing speed, navigating changing terrain (hills, sand traps, varying heights of grass), tracking and finding balls, paying attention to other golfers, analyzing wind conditions, putting slopes and putting speed, and continuously keeping score, while following the rules of the game. Because of these multi-tasking golf-related cognitive activities, we hypothesized that estimated changes in DT walking speed, DT walking speed cost and measures of cognition would demonstrate medium to large ES's. Estimated DT walking speed increased by 9.1% with a medium-large ES and was associated with estimated increases in CAD (5.8%) and to a smaller extent, SL (2.6%) with medium and small ES's, respectively. Estimated change in DT walking speed cost, however, was small and had a small ES, suggesting that the estimated improvements in DT walking speed could be accounted for by improvements in walking speed, and not a reduction in cognitive interference. These findings are consistent with two systematic reviews and meta-analyses which summarized that although physical activity programs tend to improve DT walking speed, these improvements can largely be attributed to increased walking speed and not a reduction in DT costs (Al-Yahya et al., 2011; Plummer et al., 2016). The methods we used to assess DT walking speed are well accepted, valid, and reliable in older adults (Muhaidat et al., 2013). We were able to automate the collection and processing of these data using the ProtoKinetics Zeno Walkway and associated software (ProtoKinetics, Havertown, PA). These data, however, could also be collected using a stopwatch, cones, and an unobstructed runway, which would be less expensive and facilitate data collection across several locations in an expanded RCT.

The golf program also demonstrated medium-large ES improvements in cognition, including CVLT composite score (0.85) and immediate recall (0.75) and NIH–C composite (0.39) and card-sorting (0.37). These findings are consistent with two recent systematic reviews and meta-analyses (Barha, 2017; Erickson, 2019) which reported that there was moderate evidence for an effect of moderate to vigorous physical activity on improving cognitive outcomes in older adults. In these reports, Hedges g's ranged from 0.2 to as high as 2.8 for improvements in executive function. It was noted that the largest ES's were associated with studies using aerobic training, compared to resistance or multi-modal training. Moreover, studies that had a higher percentage of female participants demonstrated the greatest ES's. The current study had an equal number of males and females and did not include a large enough sample size to examine the effects of sex. And although golf is considered a multi-modal physical activity, it is also considered a moderate-intensity physical activity for seniors with a metabolic demand of approximately 4 times resting rate (Cann et al., 2005; Drobrosielski, 2002).

Few other studies have assessed the effects of golf programs for non-golfing older adults. Shimada et al. (2018) conducted a 24 week, once-weekly, 1.5–2 h per session, golf study to assess the changes in cognition in a population of healthy people aged 65 or more years who did not play golf more than twice per year. They reported improvements in logical, but not episodic memory (as assessed through word recall), attention, and executive function. The present study was, however, able to demonstrate medium ES in estimated improvements in episodic memory as well as in composite cognition (as assessed from the NIH Toolbox tests). There are likely several reasons for the disparities between the two studies, such as the duration of the programs (24 weeks vs 10 weeks) and the days per week of participation. As the aim of the Shimada et al. study was to actively improve cognitive function, participants were additionally asked to perform "home-based" golf practice each day and were encouraged to continue "learning" about golf.

Our research group recently reported that a 12-week golf program for older male military veterans at a Veterans Administration was safe (no adverse events or participant drop-outs), adherent (91% attendance), and demonstrated large effects for estimated improvements in chair-stand, 8-foot-up-and-go time, and dynamic postural control (Du Bois et al., 2021). The present study expanded the scope of the previous investigation to include a more diverse cohort (i.e. females and non-veterans) and be conducted within the local community at a public course. Additionally, the current golf program was only 10 weeks compared to 12 weeks in the earlier study. Combined, these reports support that golf may be a feasible, adherent, and safe, multi-modal, cognitively-complex recreational activity which may improve physical fitness and cognition in non-golfing older adults. Study limitations, however, hinder our ability to definitively determine if the estimated effects are real. For example, the current pilot study had a relatively small sample size that did not include an active-control or delayed-intervention group. Thus, an expanded, well-controlled, RCT, that includes blinding of the research associates, will be necessary to verify the current findings. Additionally, the participants were all healthy older adults, who were cleared by their physicians to participate in the program, were actively participating in other physical activities, and who demonstrated fast baseline walking speeds—an accepted measure of overall senior health and wellness. Thus, it is not clear if the program would be feasible, safe, or adherent, in a less active or less physically fit group of participants.

An important goal of the study was to determine required sample sizes for an adequately powered, two-arm, follow-up RCT. The findings suggest that with a feasible sample size of 50 participants per group, the study would be adequately powered to test the efficacy of the program in improving ST and DT walking speed and cadence, ST stride length, CVLT composite score and immediate recall, and NIH Toolbox composite score and card sorting ability.

5. Conclusion

The current study was a non-randomized, pre-post, pilot study that examined whether non-golfing older adults aged 60–80 could feasibly and safely participate in a golf program and potentially improve ST and DT walking speed and cognition over a 10-week period. Findings suggest that the program was feasible, adherent, and safe, and demonstrated medium-large ES's in estimated improvements of ST and DT walking speed and cognition. Participants also self-reported improved physical function, and mental and social well-being, and all participants planned to continue playing golf. These findings support the development of an expanded two-arm, delayed-intervention or parallel-treatment RCT with a sample size of 50 participants per group.

Source of funding

The R&A Golf Association.

Funding

This work was supported by a grant from The R&A Golf Association.

Declaration of competing interest

None.

Acknowledgements

Sincere appreciation to Karen Lee, M.S., and Kevin Norwall for their help with participant training and testing.

Appendix A. Exit Survey

We would like to learn about your thoughts regarding participation in the Golf for Healthy Aging study. In one or two brief sentences, please answer the following questions …

1. In your opinion, how has your involvement in the 12-week GHA study affected your
   a. physical function (for example: physical endurance, strength, flexibility, sleep, other)?
   b. mental wellbeing (for example: stress, anxiety, concentration, memory, other)?
   c. social wellbeing (for example: support, friendship, trust)?
2. Will you continue to play golf once the study is over? If so, where will you play?

Appendix B. Exit Survey Results

	Physical	Mental	Social	Continue golf?
GHA01	All	it definitely helps		same place
GHA03	warm ups aided flexibility and endurance	The concentration needed in golf provides escape from outside stress. Memory seems to improve because of new skills learned	excellent activity for making friends and improving social skills	I will play locally - Monterey Park, Almansor, Whittier Narrows
GHA07	more flexibility. Endurance increased	No stress. Relaxed as I improved my golf abilities		Absolutely. I have already scheduled times with friends to golf
GHA13	all are better. I get tired after the golf game and sleep well. I walk faster when I take the dog out.	I think I am doing better with my stress levels and now I have a new outlet.	I feel more confident in my relationships.	Yes. I will play at 9 hole courses and will return to Monterey park golf course.
GHA15	No noticeable difference in endurance or strength, but I use different muscles in golf than in my other activities.	I think it has improved my concentration	It will improve circle of friends as beginner golfers. It will give us a fun activity to keep moving as we socialize.	Yes. I will probably play at Heartwell 18-hole, par 3 in Long Beach to begin my 100 rounds of golf.
GHA16	I feel like doing more. I was having trouble sleeping. Not anymore, I am sleeping well.	I feel more relaxed	When asked I am now saying yes to doing more things	Yes. I will continue to play, maybe in Long Beach.

(continued on next page)

(*continued*)

	Physical	Mental	Social	Continue golf?
GHA21	I have improved a lot	Do not know if there is a difference. It did change my feelings towards golf	It opens up another way of enjoying friendship	Yes. Around LA. My son and sons-in-law are waiting for me to take them to some fancy golf resort.
GHA20	Getting stronger	Relaxed more and happier	Friendship	Yes. Monterey Park
GHA22	I believe all have improved. (I have always slept well).	Stress over learning a new game was definitely reduced. Focus and concentration definitely improved. Memory maybe.	We had a very cordial and friendly cohort. Staff were so supportive, feeling very safe and cared for.	Yes. Probably at Marshal Canyon, Sierra la Verde, San Dimas - they are close to my home and on travel trips.
GHA28	Reduced endurance for other sports. Flexibility improved. Sleep same.	Less stress. Concentration seems worse. Long term memory great, short may be better. Happier.	I seem to be more tolerant	Yes. Where I find friends who play.
GHA33	It is my belief all my physical functions increased. Partly because it was a new physical routine. This had me monitoring those functions and being mindful of them.	Am in mental well being. As I was increasing my physical activity my ability to handle stress increased.	During this time there was a major breach in an important friendship. Having said that, I was able to handle the situation well.	I hope so. I live close to Monterey Park so I hope to play there.
GHA29	I improved my endurance and some flexibility	It helped me a little with concentration	about the same	Yes, Long Beach area. (ie where they live)
GHA30	Better flexibility with the exercises we do before and after golf	Reduces my stress because I must be focused on golfing …. ?	Everyone in my group were like cheer leaders. I met great people on my team.	Yes. There are several courses in our area and already trying to schedule dates to play.
GHA31	Good	good	good	yes

References

Ainsworth, B. E., Haskell, W. L., Whitt, M. C., Irwin, M. L., Swartz, A. M., Strath, S. J., et al. (2000). Compendium of physical activities: An update of activity codes and MET intensities. *Medicine & Science in Sports & Exercise, 32*(9; SUPP/1), S498–S504.

Al-Yahya, E., Dawes, H., Smith, L., Dennis, A., Howells, K., & Cockburn, J. (2011). Cognitive motor interference while walking: A systematic review and meta-analysis. *Neuroscience & Biobehavioral Reviews, 35*, 715–728.

Amboni, M., Barone, P., & Hausdorff, J. M. (2013). Cognitive contributions to gait and falls: Evidence and implications. *Movement Disorders, 28*, 1520–1533.

Barha, C., Davis, J., Falck, R., Nagamatsu, L., & Liu-Ambrose, T. (2017). Sex differences in exercise efficacy to improve cognition: A systematic review and meta-analysis of randomized controlled trials in older humans. *Frontiers in Neuroendocrinology*, (46), 71–85.

Cann, A. P., Vandervoort, A. A., & Lindsay, D. M. (2005). Optimizing the benefits versus risks of golf participation by older people. *Journal of Geriatric Physical Therapy, 28*, 85–92.

Chase, J. A. D. (2015). Interventions to increase physical activity among older adults: A meta-analysis. *The Gerontologist, 55*, 706–718.

Cole, K. R., Yen, C. L., Dudley-Javoroski, S., & Shields, R. K. (2021). NIH toolbox cognition battery in young and older adults: Reliability and relationship to adiposity and physical activity. *Journal of Geriatric Physical Therapy, 44*, 51–59.

Drobrosielski, D. A., Brubaker, P. H., Berry, M. J., Ayabe, M., & Miller, H. S. (2002). The metabolic demand of golf in patients with heart disease and in healthy adults. *J Cardiopulm Rehabil.*, (22), 96–104.

Du Bois, A. M., Marcione, N. A., Castle, S. C., Moore, J. L., & Salem, G. J. (2019). The golf intervention for veterans exercise (GIVE) study: Golf training program and study design - a methodological protocol. *International Journal of Golf Science, 7*(2), 1–16.

Du Bois, J., Powers, C., Flanagan, S., Schroeder, T., Castle, S., Moore, J., et al. (2021). The effects of a comprehensive golf training program on measures of physical performance and dynamic balance in older military veterans. *International Journal of Golf Science, 9*(1), 1–16.

Dunlap, J., & Barry, H. C. (1999). Overcoming exercise barriers in older adults. *The Physician and Sportsmedicine, 27*(11), 69–75.

Eldridge, S. M., Chan, C. L., Campbell, M. J., Bond, C. M., Hopewell, S., Thabane, L., et al. (2016). CONSORT 2010 statement: Extension to randomised pilot and feasibility trials. *BMJ, 355*.

Erickson, K. I., Hillman, C., Stillman, C. M., Ballard, R. M., Bloodgood, B., Conroy, D. E., et al. (2019). Physical activity, cognition, and brain outcomes: A review of the 2018 physical activity guidelines. *Medicine & Science in Sports & Exercise, 51*(6), 1242.

Hortobágyi, T., Lesinski, M., Gäbler, M., VanSwearingen, J. M., Malatesta, D., & Granacher, U. (2015). Effects of three types of exercise interventions on healthy old adults' gait speed: A systematic review and meta-analysis. *Sports Medicine, 45*, 1627–1643.

Jetté, M., Sidney, K., & Blümchen, G. (1990). Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clinical Cardiology, 13*, 555–565.

Kelly, M. E., Loughrey, D., Lawlor, B. A., Robertson, I. H., Walsh, C., & Brennan, S. (2014). The impact of cognitive training and mental stimulation on cognitive and everyday functioning of healthy older adults: A systematic review and meta-analysis. *Ageing Research Reviews, 15*, 28–43.

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology, 4*, 863.

Law, L. L., Barnett, F., Yau, M. K., & Gray, M. A. (2014). Effects of combined cognitive and exercise interventions on cognition in older adults with and without cognitive impairment: A systematic review. *Ageing Research Reviews, 15*, 61–75.

Muhaidat, J., Kerr, A., Evans, J. J., & Skelton, D. A. (2013). The test-retest reliability of gait-related dual task performance in community-dwelling fallers and non-fallers. *Gait & Posture, 38*(1), 43–50.

Murray, A. D., Daines, L., Archibald, D., Hawkes, R. A., Schiphorst, C., Kelly, P., et al. (2016). The relationships between golf and health: A scoping review. *British Journal of Sports Medicine, 51*(1), 12–19.

National Center for Complementary and Integrative Health. (2021). Framework for developing and testing mind and body interventions. https://www.nccih.nih.gov/grants/framework-for-developing-and-testing-mind-and-body-interventions.

Picorelli, A. M. A., Pereira, L. S. M., Pereira, D. S., Felício, D., & Sherrington, C. (2014). Adherence to exercise programs for older people is influenced by program characteristics and personal factors: A systematic review. *Journal of Physiotherapy, 60*, 151–156.

Plummer, P., Zukowski, L. A., Giuliani, C., Hall, A. M., & Zurakowski, D. (2016). Effects of physical exercise interventions on gait-related dual-task interference in older adults: A systematic review and meta-analysis. *Gerontology, 62*, 94–117.

Rivera-Torres, S., Fahey, T., & Rivera, M. (2019). Adherence to exercise programs in older adults- informative report. *Gerontology and Geriatric Medicine, 5*(3), 1–10.

Seidler, R. D., Bernard, J. A., Burutolu, T. B., Fling, B. W., Gordon, M. T., Gwin, J. T., et al. (2010). Motor control and aging: Links to age-related brain structural, functional, and biochemical effects. *Neuroscience & Biobehavioral Reviews, 34*, 721–733.

Shimada, H., Lee, S., Akishita, M., Kozaki, K., Iijima, K., Nagai, K., & Toba, K. (2018). Effects of golf training on cognition in older adults: A randomised controlled trial. *Journal of Epidemiology & Community Health, 72*, 944–950.

Snowden, M., Steinman, L., Mochan, K., Grodstein, F., Prohaska, T. R., Thurman, D. J., et al. (2011). Effect of exercise on cognitive performance in community-dwelling older adults: Review of intervention trials and recommendations for public health practice and research. *Journal of the American Geriatrics Society, 59*, 704–716.

Weintraub, S., Dikmen, S. S., Heaton, R. K., Tulsky, D. S., Zelazo, P. D., Bauer, P. J., & Fox, N. A. (2013). Cognition assessment using the NIH Toolbox. *Neurology, 80*(11 Supplement 3), S54–S64.

Williams, K. N., & Kemper, S. (2010). Interventions to reduce cognitive decline in aging. *Journal of Psychosocial Nursing and Mental Health Services, 48*(5), 42–51.

Woods, S. P., Delis, D. C., Scott, J. C., Kramer, J. H., & Holdnack, J. A. (2006). The California verbal learning test–second edition: Test-retest reliability, practice effects, and reliable change indices for the standard and alternate forms. *Archives of Clinical Neuropsychology, 21*(5), 413–420.

Woollacott, M., & Shumway-Cook, A. (2002). Attention and control of posture and gait: A review of an emerging area of research. *Gait & Posture, 16*, 1–14.

Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., Conway, K. P., et al. (2014). NIH toolbox cognition battery (CB): Validation of executive function measures in adults. *Journal of the International Neuropsychological Society, 20*, 620.

Zettergren, K. K., Lubeski, J. M., & Viverito, J. M. (2011). Effects of a yoga program on postural control, mobility, and gait speed in community-living older adults: A pilot study. *Journal of Geriatric Physical Therapy, 34*, 88–94.