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Effect of Cognitive Remediation on Gait in Sedentary Seniors

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Background. Attention and executive functions show strong associations with slow gait and falls in seniors and have been shown to be amenable to cognitive remediation. However, cognitive remediation as a strategy to improve mobility has not been investigated.

Methods. Using a randomized single-blind control design, 24 sedentary older adults (exercise less than or equal to once weekly and gait velocity <1 m/s) were randomly assigned to an 8-week computerized cognitive remediation program or wait-list. Primary outcome was change in gait velocity during normal pace and "walking while talking" conditions. We also compared the proportion of improvers (velocity change ≥4 cm/s) in each group.

Results. The 10 participants who completed cognitive remediation improved gait velocity from baseline during normal walking (68.2 ± 20.0 vs 76.5 ± 17.9 cm/s, $p = .05$) and walking while talking (36.7 ± 13.5 vs 56.7 ± 20.4 cm/s, $p = .002$). The 10 intervention participants improved gait velocity over the 8-week intervention both during normal walking (change: 8.2 ± 11.4–1.3 ± 6.8 cm/s, $p = .10$) and walking while talking (change: 19.9 ± 14.9–2.5 ± 20.1 cm/s, $p = .05$) compared with the 10 control participants. Six intervention participants were improvers on normal pace walking compared with three controls (odds ratio = 3.0, 95% confidence interval = 0.5–19.6). All 10 intervention participants improved on walking while talking compared with 3 controls (odds ratio = 3.5, 95% confidence interval = 1.5–8.0).

Conclusions. The findings of this pilot trial are promising and suggest that cognitive remediation may improve mobility in sedentary seniors. This approach should be validated in larger scale trials.

Key Words: Cognitive remediation—Gait velocity—Attention.

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THE prevalence of mobility disability increases with age (1). People with mobility disabilities are less likely to remain in the community, have higher rates of morbidity and mortality, and experience poor quality of life (2). Physical exercise, especially walking, is recommended to prevent mobility disability and is supported by a large body of research (3). Despite the widely reported benefits of physical exercise in both scientific and popular media, participation is low among seniors (3,4). Adherence is low among those starting physical exercise; 50% of individuals joining exercise programs drop out in the first 3–6 months (5). Seniors bear a large burden of disability and diseases amenable to prevention and treatment with physical exercise. Yet, they often have the least access and opportunity for physical exercise (4). Hence, it is vital to explore other approaches to improve mobility.

"Attention and executive functions" are a set of higher cognitive processes that modulate behavior, allocate resources among simultaneous tasks (divided attention), anticipate outcomes, and adapt to changing situations (6). Attention and executive functions have important links to mobility (7–12). Impairments in attention and executive functions are associated with slow gait and falls in older adults (7,8,10,12,13). Pharmacological interventions targeting attention and executive functions have been reported to improve gait (14). Cognitive remediation interventions have been shown to improve attention and executive functions as well as memory in seniors (15–17). Despite these promising results, cognitive remediation targeting attention and executive functions as a strategy to improve mobility has not been explored. Furthermore, transfer of training effects following cognitive remediation to nontrained cognitive domains or distal functions like mobility have not been established (16).

To address this issue, we conducted a preliminary randomized single-blind clinical trial to test the potential effect of cognitive remediation focused primarily on attention and executive functions to improve gait in sedentary seniors using a widely available commercial computerized brain

fitness program (Mindfit; CogniFit Inc., Yokneam, Israel) (18). Our main outcome was change in gait velocity following the intervention during normal pace walking as well as during a more attention demanding "walking while talking" (WWT) task (11,19).

Methods

Eligibility and Study Design

A randomized single-blind controlled proof of concept clinical trial evaluated the efficacy of cognitive remediation on improving gait in sedentary seniors using a two-group design: intervention and wait-list control. Potential participants were identified through the Bronx county Board of Elections voter registration lists for adults aged 70 years and older. Potential participants were sent a letter explaining the nature and purpose of the study followed by a telephone call by a research assistant a few days later. After obtaining verbal consent, a brief interview to identify sedentary participants and a validated cognitive screen to exclude dementia were administered (20). Individuals who met our study criteria on the telephone interview were invited for further in-person screening at our research center.

The in-person assessment included cognitive (Mini-Mental State Examination (21); MMSE) and gait assessments by a research assistant as well as a clinical evaluation by the study clinicians to assess final eligibility. Inclusion criteria were aged 70 years and older, ability to make time commitment, and sedentary (physically inactive or exercises once weekly or less (22)). From among individuals meeting the sedentary criteria, recruitment was further restricted to those with gait velocity <1.0 m/s. This cut score was selected because it has been shown to be a useful threshold for future disability (23,24) and would identify a group at high risk for mobility decline for this proof of concept trial. Exclusion criteria included presence of dementia (telephone Memory Impairment Screen score ≤5 (20), MMSE score ≤25, or dementia diagnosed by study clinicians), inability to ambulate, hospitalized in past 3 months for severe illness or surgery, major neurological or psychiatric illness history, or concurrent enrollment in other studies.

Eligible participants following in-person screening were assigned to either cognitive remediation or wait-list control using a fixed randomization scheme with assignment based on a table of random numbers. The study protocol was approved by the institutional review board. Written informed consent was obtained from all study participants. Study participants did not receive any monetary compensation but were provided transportation to attend all sessions.

Cognitive remediation.—Only 2 out of 12 participants in the intervention group reported using a computer. Hence, the first training session conducted within a week of randomization was devoted to teaching basic computing skills, such as how to use a mouse. The Mindfit program includes a 45-minute baseline cognitive assessment that allows the training program to be tailored for each participant based on his or her individual cognitive strengths and weaknesses (18). Normative data from a large database of previous users define the initial challenge level of each of the training tasks. Each training session included a mixture of 21 visual, auditory, and cross-modality tasks aimed at training attention and executive functions and other cognitive processes. Each scheduled training consisted of two sessions (15–20 minutes each) that contained three different tasks each. Written and verbal instructions were provided by the program before each task. The tasks were then demonstrated on the computer screen. Each of the three tasks has three levels of difficulty—easy, moderate, and difficult. The level of challenge was further readjusted after each training session according to the participant's progress. The Mindfit program has an additional "task pool" feature, which includes all 21 training tasks. We utilized the task pool for an additional focused attention and executive functions training session for 15–20 minutes after the two scheduled training sessions were completed. At the end of each task's daily training, participants could examine their performance on graphs that described their progress. Participants received remediation for 45–60 minutes three times weekly for 8 weeks (72 total sessions) with at least a 1-day interval between training days. There was a very high rate of participation; participants attended 99.2% of the sessions.

Wait-list control.—Control participants were informed that they were on a wait-list for participation in future studies at our center. The wait-list controls had an initial health education session stressing the benefits of exercise. All patients, regardless of treatment group, received detailed educational materials, in the form of a booklet, at the time of enrollment, including information on activity level of 30 minutes (as tolerated) of moderate-intensity activity on most days of the week consistent with national guidelines as well as a list of exercise facilities in their local neighborhoods (3). The cognitive remediation intervention was not revealed to the controls. Wait-list controls were contacted by telephone by research assistants to maintain adherence and interest in this trial but did not have in-house sessions. During these calls, participants were asked questions to determine if they were exercising, but no further information was obtained due to concerns that more detailed questions about exercise would promote exercise behavior among patients in the wait-list group.

Outcome Measures

Assessments were undertaken at baseline and after the 8-week intervention by a research assistant who did not participate in the interventions and was blinded to group assignment.

Gait.—Gait speed, the primary outcome, was measured using a computerized walkway (GAITRite) (25). Gait velocity has been compared with a measure of vital signs in older adults, a screening measure that reflects integration of health, disease, fitness, and emotional state (24). Gait velocity is used to describe recovery (26) and to establish thresholds in community-based activities, such as ability to cross a street (27). Gait velocity is associated with activity levels (28), functional status (29), and falls (30).

Participants were asked to walk on the mat at their usual pace for two trials in a quiet well-lit hallway wearing comfortable footwear and without any attached monitors. Start and stop points were marked by white lines on the floor and included 3 feet from the walkway edge for initial acceleration and terminal deceleration. For the WWT condition, participants were asked to walk the same course for two trials while reciting alternate letters of the alphabet. Participants were given practice trials as required. The order of the initial letter on WWT was randomly varied between "A" and "B" to minimize practice effects as previously described (19). The GAITRite system is widely used in clinical and research settings, and excellent reliability has been reported in our and other centers (19).

Additional variables.—MMSE was readministered at the end of the intervention (21). We assessed speed of processing in millisecond reaction time in the cognitive remediation group to assess "near transfer" of training effects to cognitive domains related to the cognitive processes trained (16,31,32). Self-reported presence of illnesses (depression or anxiety, diabetes, heart failure, hypertension, angina, myocardial infarction, strokes, Parkinson's disease, chronic obstructive lung disease, cancer, tremors, and arthritis) relevant to rehabilitation interventions was used to calculate a summary illness index (total 12 points) as previously described (25). All participants were asked to complete a physical activity questionnaire that quantified the amount of moderate or vigorous activity in minutes per week completed during the preceding week.

Analysis

Descriptive statistics were used to compare demographic and other baseline characteristics within and between the two groups (33). Differences in mean pre- and posttreatment gait velocity were tested simultaneously on normal walking and WWT conditions using mixed linear models (34). All models were adjusted for age and sex. Postintervention changes in speed of processing in the cognitive remediation group were also assessed with mixed linear models (34). We have reported that a 4-cm/s change in gait velocity over 1 year is a small but clinically meaningful change in our population (35). Hence, we studied improvers defined using this cutscore with logistic regression (33). Given the pilot nature of the study and small sample size, intent-to-treat analysis was not done. Furthermore, although last observation carried forward is used to deal with missing data in many clinical trials, many concerns have been raised, including ignoring trends in data, reducing variability arbitrarily, and overestimating precision of parameter estimates (36). All statistical analyses were performed using SAS 9.1 (SAS Institute Inc., Cary, NC).

Table 1. Table of Baseline Characteristics

Variables	Intervention	Control	*p* Value
N	12	12	
Age (y)	77.4 ± 7.0	79.9 ± 7.5	.41
Female, *n*	8	7	.79
Education, y	14.3 ± 2.9	13.1 ± 2.7	.28
Illness index score (0–12)	2.2 ± 1.0	1.7 ± 0.9	.33
Self-reported difficulty walking, *n*	9	8	.51
Fall in the last 12 months, *n*	3	2	.99
MMSE scores (0–30)	29.0 ± 0.3	29.1 ± 0.4	.87
MIS scores (0–8)	7.4 ± 0.6	7.2 ± 0.6	.51
Normal pace gait velocity, cm/s	69.2 ± 18.7	74.7 ± 18.6	.53
WWT velocity, cm/s	36.1 ± 12.4	45.2 ± 20.1	.29

Note: All values are means ± *SD* unless otherwise stated. MMSE = Mini-Mental State Examination; MIS = Memory Impairment Screen; WWT = walking while talking.

Results

Group Characteristics

From a referral pool of 45 individuals screened for eligibility on our telephone interview, we recruited 24 people who met our pilot study criteria. Participant characteristics are documented in Table 1. There were no significant differences on key demographic characteristics or gait velocity between the 12 intervention (8 females and 4 males) and 12 wait-list (7 females and 5 males) participants at baseline. The cognitive test scores in both groups (Table 1) confirmed overall intact mental status. This was a frail sample with a high prevalence of self-reported walking difficulty and slow gait velocity in both groups. Two intervention participants (one required abdominal surgery and another developed cardiac failure) and two control participants (one had a viral illness and one refused without giving a reason) did not complete the 8-week postintervention visit. By the end of the study, there were 20 participants (83.3%) remaining from the initial sample. There were no significant differences in age, gender, or baseline gait velocity between the participants who dropped out and those who completed the study. A Consolidated Standards of Reporting Trials flow diagram of the progress of the sample through the phases of the study and reasons for exclusions is provided in Figure 1.

Primary Outcomes

Compared with baseline, the 10 participants who completed the 8-week cognitive remediation program improved their gait velocity during normal pace walking (68.2 ± 20.0–76.5 ± 17.9 cm/s, $p = .05$) and on the WWT condition (36.7 ± 13.5–56.7 ± 20.4 cm/s, $p = .002$). On the other hand, the control group did not improve gait velocity on either normal

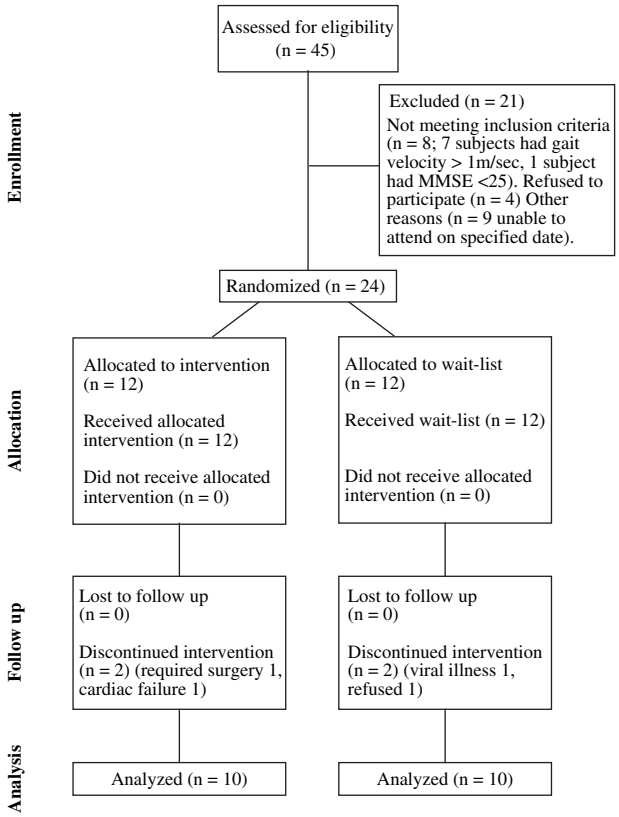

Figure 1. CONSORT diagram showing the flow of participants.

walking (76.2 ± 17.9–77.4 ± 21.3 cm/s, $p = 0.57$) or WWT (47.2 ± 13.5–49.7 ± 20.3 cm/s, $p = 0.70$) after 8 weeks.

The 10 intervention participants improved gait velocity over the 8-week intervention both during normal walking (change: 8.2 ± 11.4–1.3 ± 6.8 cm/s, $p = .10$) as well as during WWT (change: 19.9 ± 14.9–2.5 ± 20.1 cm/s, $p = .05$) compared with the 10 control participants. Figure 2 shows boxplots of change in gait velocity compared with baseline during the two gait conditions. One outlier in each intervention group had changes on WWT in the expected direction as shown in Figure 2.

Six out of the 10 cognitive remediation participants improved gait velocity 4 cm/s or more on normal walking in 8 weeks compared with 3 out of 10 participants in the control group (odds ratio = 3.0, 95% confidence interval = 0.5–19.6). All 10 cognitive remediation participants showed a 4 cm/s or greater improvement on WWT velocity compared with 3 out of 10 controls (odds ratio = 3.5, 95% confidence interval = 1.5–8.0).

Pearson correlations on gait velocity before and after the intervention were .86 for the normal pace and .49 for WWT conditions (33).

Additional Measures

The MMSE scores did not significantly change (higher better) over the study period in the remediation (mean

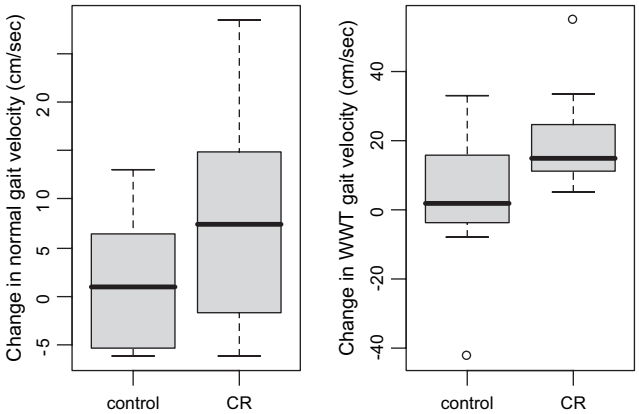

Figure 2. Boxplots of change in gait velocity in the cognitive remediation (CR) and control groups following the intervention. Note that the range on the y-axis is different in the two plots. The line in the middle of the box represents the median value. The ends of the box represent the 25th and 75th quartile values. The bars show the range of scores and circles are outliers.

change from baseline: +0.6 points) and control groups (−0.3points, $p > .10$). Speed of processing improved by 1,662 ms (95% confidence interval = 155–3168 ms, $p = .03$) following cognitive remediation.

Observations

No adverse events related to the interventions were reported. All intervention participants reported at the end of the study that they enjoyed participating in the cognitive remediation program and gaining computer skills. None of the participants in either group reported an increase in their physical exercise frequency (from once weekly or less) at the end of 8 weeks or joining an exercise facility. The two intervention participants with prior computer familiarity reported increasing their computer use to play puzzles after the intervention, and another participant in the intervention group proceeded to buy a personal computer.

Discussion

The findings of this pilot randomized clinical trial show that a computerized cognitive remediation program improved gait in sedentary seniors. The ready adoption of this form of cognitive remediation by frail seniors who were mostly computer novices was encouraging. Our experience supports the feasibility of computerized remediation approaches in seniors (17,37). The intervention group had better gait performance at the end of the 8-week cognitive remediation compared with their baseline; an improvement was not observed in the controls. The postintervention change in normal pace gait velocity in the intervention group compared with the controls was not significant in this small sample but was suggestive. A larger effect was seen following the intervention on the more attention-demanding WWT task in the remediation group compared with control participants.

The improvement in speed of processing in the cognitive remediation participants in our study supports near transfer of training effects of the computerized cognitive remediation program as shown in previous clinical trials (16,17). Speed of processing has been shown to affect other cognitive abilities, which may depend on it as a core resource to process information (31,32). To our knowledge, this is the first study to demonstrate far transfer of cognitive remediation effects to a distal untrained domain, such as mobility. Transfer of gains from trained domains to untrained domains has been demonstrated in some but not all cognitive remediation trials (16,17,37). Though none of these previous studies have assessed mobility outcomes, some reports suggest that cognitive remediation may improve everyday functioning and driving behavior (15,38,39). The cognitive remediation targeting attention and executive functions may have translated into more efficient walking patterns during WWT given the strong association between this cognitive process and WWT. WWT has been considered an ecologically valid task reflecting real world function and predicts risk of adverse outcomes, such as falls (40). Moreover, the dual task processes involved in WWT are amenable to training (11,41,42). Although the WWT is an attention-demanding task (8), in this clinical trial, improvement was demonstrated on WWT's motor output supporting far transfer of cognitive remediation effects to distal untrained mobility processes.

A broad approach targeting multiple domains may be more effective than targeting single or limited set of cognitive processes. This broad approach may be especially relevant to gait that engages multiple cognitive processes (8). Speed of processing is a common underlying construct for the cognitive processes targeted by remediation (16,31). Our chosen software included exercises not only aimed to improve speed of processing but also trained on other tasks that were relevant to gait, such as divided attention, visuospatial skills, and executive functions (18). It is likely that other computerized or noncomputerized cognitive remediation programs targeting attention and executive functions may also achieve similar mobility benefits. Due to our small sample, we were unable to examine the independent dose effect of training on different cognitive domains on our outcomes and plan to do so in future larger scale studies.

Given the pilot nature of this clinical trial, a number of limitations need to be noted. Though we used a simple randomization procedure and there were no group differences at baseline in key variables, the mean gait velocity was nonsignificantly higher in the controls. Hence, our group comparisons may have underestimated change following intervention because of better gait in controls. We plan to follow up our participants to assess durability of observed effects. Conventional neuropsychological tests were not done as we did not anticipate significant changes over the very short intervention period in this small sample, as seen with MMSE. In future larger scale studies, we plan to include more sensitive cognitive measures to better understand near transfer effects of cognitive remediation. The observed mobility effects may also be due to changes in mood, self-efficacy, or motivation that were not measured. There were no changes in reported physical activity or exercise levels following the intervention to account for better gait. Participants were provided transportation to and from the intervention sessions. Nonetheless, a minor effect of attending intervention sessions on increasing activity levels during the intervention period cannot be excluded. The number of interactions with study personnel was not balanced between groups. However, a previous study found no improvement in physical function after a program of preventive home visits, despite repeated contacts between participants and research staff (43). More comprehensive documentation of activity and alternate pathways needs to be considered in future studies. It would also be important to study whether there is an additive benefit of combining physical and cognitive exercises on mobility.

Our results are promising but need to be followed up with larger scale trials to establish the validity of cognitive approaches to treating mobility decline. A U.S. Census Bureau community survey in 2003 (44) reported that 35% of adults older than 65 years of age and 63% of adults between ages 55 and 64 years have a computer at home. These figures are likely higher today, suggesting a huge potential audience for computerized cognitive remediation programs. Based on our preliminary results, to detect a minimal but clinically meaningful gait velocity difference of 4 cm/s between groups with 85% power would require a sample size of 400 sedentary seniors (200 per group) after accounting for attrition (35). Establishing mobility gains with cognitive remediation will introduce a new low-risk and accessible treatment option as an alternative or supplemental strategy for many seniors who do not engage in physical exercise due to physical, medical, motivational, or socioeconomic reasons (5).

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