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A Randomized Trial to Measure the Impact of a Community-Based Cognitive Training Intervention on Balance and Gait in Cognitively Intact Black Older Adults

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Abstract

Introduction—Fall prevention is important for maintaining mobility and independence into old age. Approaches for reducing falls include exercise, tai chi, and home modifications; however, causes of falling are multifactorial and include not just physical but cognitive factors. Cognitive decline occurs with age, but older adults with the greatest declines in executive function experience more falls. The purpose of this study was twofold: to demonstrate the feasibility of a community-based cognitive training program for cognitively intact Black older adults and to analyze its impact on gait and balance in this population.

Method—This pilot study used a pretest/posttest randomized trial design with assignment to an intervention or control group. Participants assigned to the intervention completed a computer-based cognitive training class that met 2 days a week for 60 min over 10 weeks. Classes were held at senior/community centers. Primary outcomes included balance as measured by the Berg Balance Scale (BBS), 10-meter gait speed, and 10-meter gait speed under visuospatial dual-task condition. All measures were assessed at baseline and immediately post-intervention.

Results—Participants were community-dwelling Black adults with a mean age of 72.5 and history of falls ($N = 45$). Compared to controls, intervention participants experienced statistically significant improvements in BBS and gait speed. Mean performance on distracted gait speed also improved more for intervention participants compared to controls.

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Supplemental Material

Additional supporting information is available at heb.sagepub.com/supplemental.

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Conclusion—Findings from this pilot randomized trial demonstrate the feasibility of a community-based cognitive training intervention. They provide initial evidence that cognitive training may be an efficacious approach toward improving balance and gait in older adults known to have a history of falls.

Keywords

aging and health; community health; computer-mediated health promotion; health behavior new media and social media interventions

Each year, approximately one third of community-dwelling older adults fall (Gillespie et al., 2012). The rate of falls increases with age and approximately doubles for adults over age 75 (Rubenstein, 2006). Despite the numerous fall prevention interventions that have been tested, a high incidence of falls persists nationally (Adams, Martinez, Vickerie, & Kirzinger, 2011).

Causes of falling are multifactorial and include both physical and cognitive factors. A growing body of research provides support for the relationship between the central nervous system—in particular, cognition—and mobility. Executive function (EF), a specific component of cognitive processing, is known to play an important role in gait and mobility (Al-Yahya et al., 2011; Fasano, Plotnik, Bove, & Berardelli, 2012; Mirelman et al., 2012). Although the exact mechanisms underlying the association between cognition and mobility are still being explored, studies show that gait variability in older adults is associated with atrophy in brain regions that are related to attention (Rosano, Newman, Katz, Hirsch, & Kuller, 2008) and that global cognitive function, verbal memory, and EF predict longitudinal gait speed decline (Watson et al., 2010). Gait speed and balance have been investigated for some time through the lens of biomechanics; however, it is clear that there is a shared underlying pathology that links biomechanical declines in gait speed with cognition. Despite these age-related changes, we also know that the aging brain has exceptional neuroplasticity (Reuter-Lorenz & Cappell, 2008). Because of this plasticity, interventions targeted at training cognitive domains that are linked with mobility may improve two predictors of falls, namely, gait and balance (Lajoie & Gallagher, 2004; Maki, 1997; Shumway-Cook, Baldwin, Polissar, & Gruber, 1997).

Studies have shown that EF and dual-task ability play a central role in recovery from trips through set shifting (Anstey, Von Sanden, & Luszcz, 2006), maintaining balance through visuospatial working memory, and processing speed to maintain gait (Hsu, Nagamatsu, Davis, & Liu-Ambrose, 2012). Walking requires EF and attention in order to maintain awareness, identify and react to visuospatial demands, inhibit interferences, and allocate motor and cognitive resources while navigating through one's environment (van Iersel, Kessels, Bloem, Verbeek, & Olde Rikkert, 2008; Yogev-Seligmann, Hausdorff, & Giladi, 2008). Underscoring this connection, we now have substantial evidence demonstrating that EF and related dual-task processing decline with age (Beurskens & Bock, 2012; Salthouse, 2005; Salthouse, Atkinson, & Berish, 2003; Verhaeghen & Cerella, 2002). These documented relationships strongly suggest that age-related degradation in EF and attention impact the ability of older adults to engage in everyday dual-task scenarios (i.e., walk along

street while watching traffic) and that these decrements are responsible, at least in part, for an increased risk of falls (Herman, Mirelman, Giladi, Schweiger, & Hausdorff, 2010; Mirelman et al., 2012; Springer et al., 2006).

Cognitive training is an efficacious approach that targets specific cognitive domains in order to maintain or improve their function (Smith et al., 2009; Willis et al., 2006; Wolinsky, Vander Weg, Howren, Jones, & Dotson, 2013). The large ($N = 2,832$) Advanced Cognitive Training for Independent and Vital Elderly (ACTIVE) trial found that healthy older adults who received training on speed of processing, reasoning, and verbal episodic memory improved significantly in these domains immediately postintervention with improvements in reasoning and speed of processing maintained through 10 years (Rebok et al., 2014; Willis et al., 2006).

Although cognitive training has been used to maintain or improve cognitive functioning, it may also be a viable strategy for improving gait and balance. To date, three published studies have shown that it is possible to intervene on cognition to improve walking and balance in healthy older adults. However, these studies used small samples, were conducted in research laboratories, and were not designed for broad public health application (Doumas, Rapp, & Krampe, 2009; Li et al., 2010; Silsupadol et al., 2009). We are aware of only two small randomized trials that have used a cognitive training approach capable of broad dissemination: Smith-Ray et al. (2013) and Verghese et al (Verghese, Mahoney, Ambrose, Wang, & Holtzer, 2010).

Our previous work tested the impact of a 10-week computer-based cognitive training intervention (Posit Science) on balance and gait in older adults (Smith-Ray et al., 2013). At 10 weeks, intervention participants performed significantly better than controls on Timed Up and Go, a proxy measure of balance. Intervention participants also performed better than controls on gait speed and distracted gait speed; however, between-group differences were not significant. Verghese and colleagues (2010) also used a randomized trial to test the impact of a commercially available cognitive training program over 8 weeks on gait speed in healthy older adults. They found that older adult participants who completed the cognitive training intervention improved in gait speed and gait speed while talking compared to controls, but between-group differences were not significant, likely due to the small sample size ($N = 20$; Verghese et al., 2010). Although only a small number of studies have addressed this issue to date, as a group, their findings consistently support the plausibility of cognitive training as a strategy for improving gait and balance, thereby potentially reducing fall risk.

Unfortunately, health disparities and inequalities in the United States continue to be enormous. While Black older adults do not fall more than White older adults (De Rekeneire et al., 2003), older Blacks have higher rates of two risk factors related to balance and gait: physical inactivity and cognitive decline. Black older adults report more leisure-time physical *inactivity* than Whites (Crespo, Smit, Andersen, Carter-Pokras, & Ainsworth, 2000) and experience higher mortality associated with Alzheimer's disease (Chaix et al., 2011). Moreover, older adults living in neighborhoods deprived of resources available in middle-

class and affluent neighborhoods exhibit worse cognitive function in old age than their nondeprived counterparts (Lee, Glass, James, Bandeen-Roche, & Schwartz, 2011).

Importantly, to our knowledge, no cognitive training interventions for balance/gait have targeted ethnic/racial minorities to date. The present study builds on our and others' recent work to test the impact of a cognitive training program, delivered in community senior centers, on gait and balance in older adults. Specifically, this study sought to examine this association within a cohort of community-dwelling Black older adults. The purpose of this study was twofold: to demonstrate the feasibility of a community-based cognitive training program for cognitively intact Black older adults and to analyze its impact on gait and balance in this population. Older adults randomized to cognitive training were expected to show significant improvements in balance and gait compared to control group participants.

Method

Design

A randomized controlled trial was used to assess the efficacy of a computer-based cognitive training program on balance and gait, with measurements at baseline and immediately postintervention for all participants.

Participants

Inclusion criteria were (a) at least one self-reported fall within the last 2 years *or* unable to stand on one leg for >3 s, (b) 65 years of age or older, and (c) score greater than or equal to 26 on the Mini-Mental State Examination (Folstein, Folstein, & McHugh, 1975). Exclusion criteria were (a) presence of a significant balance or walking impairment, (b) currently involved in or recently completed a cognitive training program, (c) plans to begin a balance program (e.g., tai chi) during the study period, or (d) currently using psychotropic medication.

Procedure

All participants were recruited from community centers through presentations by research staff, flyers posted/distributed throughout the centers, word of mouth, and study advertisements printed in the monthly calendars. Older adults who were interested in participating were instructed to call the research assistant in order to be screened for eligibility. If a participant screened eligible, an appointment was arranged between the prospective participant and the research assistant to complete the informed consent and baseline measures. This study was approved by the University of Illinois at Chicago Institutional Review Board (2010-0042).

Participants were blindly randomized into the intervention or control arm. Randomization occurred at the site level so that equal numbers of participants were allocated to each study arm at each site. Researchers were not blinded to study arm condition. To minimize measurement bias, randomization occurred after collection of baseline measures. Outcomes were assessed at baseline and immediately posttraining (10 weeks) through staff interviews and observations of mobility tasks.

Control Condition—A measurement-only control condition was employed. Participants assigned to the control arm met with research staff to complete study measures at baseline and at 10 weeks but were not otherwise contacted during the 10-week study period. To ensure equitable benefits across study arms, each participant was provided the opportunity to complete the computer-based cognitive training program at the conclusion of the 10-week study at the senior/community center for no charge.

Intervention Condition—Participants randomized to the intervention completed the 10-week computer-based cognitive training program in a classroom format at the senior/community centers. Participants met for 60 min per session two times per week over a 10-week period. The computer software program Insight, developed by the Posit Science Group, was used to target EF. During the first two group sessions, the research assistant acquainted the participants to the cognitive training program. After the participants learned how to operate the program, each participant completed the computer-based intervention independently. The research assistant attended each group session to answer participant questions and assist with program and computer troubleshooting. Although the intervention was completed in a class-based setting, there was very little formal or informal social interaction among participants during each group session.

This training protocol was chosen for several reasons. First, this program was modeled from successful cognitive training programs, including the ACTIVE (Willis et al., 2006) and IMPACT trials (Smith et al., 2009). Second, the Posit Science program led to cognitive improvements in both our previous study and the Iowa Healthy and Active Minds Study (IPHAMS; Wolinsky et al., 2013). Third, the Posit Science program carefully targets EF domains, such as visuospatial working memory, speed of processing, and inhibition, through three different games that are simple to learn and play: *Road Tour*, *Jewel Diver*, and *Sweep Seeker*. The Posit Science program is self-driven and adapts to the individual's performance by increasing or decreasing task difficulty so that each participant continues to be challenged and engaged throughout the intervention. See Supplemental Table 1 (available online at heb.sagepub.com/supplemental) for a detailed description of each cognitive training game.

Measures

Screening and demographic measures were collected at baseline only and included cognitive status (Mini-Mental State Exam; Folstein et al., 1975), age, gender, education, instrumental activities of daily living, current medications, and medical conditions.

Balance and Gait Speed—Balance was measured using the seven-item brief Berg Balance Scale, a widely used, valid, and reliable measure of balance in older adults (Berg, Wood-Dauphinee, Williams, & Maki, 1992). Gait speed was measured as time to complete a 10-m walking course (10MWC). This test is a sensitive measure of gait abnormalities (van Hedel, Wirz, & Dietz, 2005). Participants were told to walk at a customary or comfortable pace. The 10MWC was completed three times, and the average (seconds) of the three performance times was used for the analysis. Following the 10MWC, participants completed another 10MWC while engaging in a secondary visuospatial task, the Brooks Matrices (Brooks, 1967). The 10MWC using the Brooks Matrices was completed three times, and the

average time (seconds) of these three performances was used for the analysis. For the Brooks Matrix condition, participants were shown a black-and-white image of a 3×3 matrix. Participants were instructed to visualize the middle square, colored black, shifting in a sequence of three locations throughout the matrix of white squares. While completing the 10MWC, the researcher called out the sequence of three moves (e.g., “The square moved one square down, one square left, two squares up”). When the 10MWC was complete, the participant was asked to point to the square in which the black square came to rest after the three moves were given.

Analysis

Analysis of variance (ANOVA) models were conducted to analyze change in mobility outcomes over the 10-week study period. Statistical models included balance score and gait speed at baseline and 10 weeks and were run using the general linear models for continuous outcomes procedure in SAS Version 9.3. A Time \times Study Arm interaction was used to identify whether significant improvements were experienced between pre- and postintervention assessments.

Results

Of 45 participants recruited into the study, 23 (51%) were randomly assigned to the intervention, while 22 (49%) were assigned to the control group. The majority of participants were female (91%), were on average 72.5 years old, and were 100% Black and not of Hispanic origin. Six participants (13%) dropped study participation and 3 (7%) were lost to follow-up. Reasons for dropping participation included the need to care for a family member (33%), personal medical concerns unrelated to the study (17%), and not enough time (17%). Two participants did not specify a reason for dropping (33%). The remaining 80% of participants completed the study. Participants who did not complete the study were slightly older (73.4 vs. 72.2), had more years of education (15.4 vs. 14.9), and had a slower baseline gait speed (10.9 s vs. 9.7 s) than those who continued their participation. Completers and noncompleters did not differ on baseline balance (BBS) or sex. Participant characteristics at baseline by study group are displayed in Table 1. There were no significant differences by group at baseline on demographic variables (age, sex, education, cognitive status) or outcome variables (gait speed, distracted gait speed, and balance). Intervention adherence, defined as 5 or more weeks of Posit Science training, was 77%. Five sessions (i.e., 5 hr) of training is equivalent to a 25% completion rate in the present study; however, the cognitive training dose required to invoke cognitive change remains unclear. For instance, the IHAMS study (Wolinsky et al., 2013) found that a 10-hr cognitive training intervention resulted in moderate improvements on cognitive measures associated with executive function, while Li et al. (2010) found that balance improved after 6 hr of training. Given what is currently known regarding cognitive training dose, it is reasonable to expect that 5 hr of training may lead to improvements.

BBS

The ANOVA analysis revealed a significant association between BBS and study arm, $F(1, 31) = 4.709, p = .038$. Mean balance as measured by BBS score improved for intervention

participants ($\mu = 1.07$) and declined slightly for control participants ($\mu = -0.11$) between baseline and 10 weeks (see Table 2). The effect size was large reflecting differences between the two groups (Cohen's $d = -0.76$).

Gait Speed

The ANOVA model revealed a significant association between 10-m gait speed (10MGS) and study arm, $F(1, 29) = 6.57, p = .016$. Between baseline and 10 weeks, intervention participants experienced a mean 10MGS improvement of greater than 1 second (change $\mu = -1.24$ s), whereas control participants experienced a slight performance decline (change $\mu = 0.09$ s) over this time. The effect size was large reflecting differences between the two groups (Cohen's $d = 0.92$).

Distracted Gait Speed

The ANOVA analysis exhibited no significant differences between study arms on 10-m distracted gait speed (10MDGS) between baseline and 10 weeks. Participants in both study arms improved their 10MDGS time between baseline and 10 weeks; however, the improvement was larger in intervention participants ($\mu = -0.86$) than for control participants ($\mu = -0.39$). The magnitude of effect between intervention and control participants was small (Cohen's $d = 0.17$).

Discussion

This pilot randomized trial of a community-based cognitive training intervention found that, compared to control arm participants, Black older adult participants who were randomly assigned to the intervention arm experienced significant improvements in balance and 10MGS. Mean performance on 10MDGS also improved more for intervention participants than controls, but between-group differences were not statistically significant. Together, these findings provide preliminary support for the hypothesis that cognitive training improves mobility (10MGS and balance) in community-dwelling Black older adults.

This pilot randomized trial also demonstrates the feasibility of a cognitive training intervention for older adults in urban senior centers. Intervention adherence (77%) and retention (80%) rates were moderate. It is likely that retention was impacted by the limited study resources (i.e., staffing) available to communicate with and track participants on a regular basis. Participants who attended the intervention on average completed 6.4 weeks of the 10-week intervention (64%). The intervention dose of 2 days a week over 10 weeks was sufficient to significantly impact balance and 10MGS; however, future studies should more carefully examine the dose response of this association and, in particular, whether a lower intervention dose might result in significant improvements in adherence and reduced attrition. Reasons provided for dropping the intervention included the need to care for a family member, not having enough time to attend the intervention classes, and unexpected illness. In other words, this pragmatic trial reflects a cohort of participants who, despite their best intentions, were unable to complete the intervention due to unanticipated demands of everyday life. We expect that our retention rate realistically reflects rates commonly seen in community-based health promotion programs.

Some of our results were contrary to those expected based on our cognitive mediational model (Smith-Ray et al., 2013). In particular, we hypothesized that participants randomized to the intervention would experience significant improvements in 10MDGS, but this is not what was observed. Although 10MDGS improved more for intervention participants than for control participants, it is not clear why these improvements were small relative to those of the other mobility outcomes. The Posit Science program specifically targets aspects of cognition that are associated with dual-task motor-cognitive processing: EF, divided attention, and visuo-spatial working memory. For this reason, we expected the training effect to be larger for distracted gait speed than for pure gait speed. In fact, our prior work supports this pattern of effects (Smith-Ray et al., 2013). One possible reason for these unexpected findings may have to do with the variability observed in the balance and gait speed measures. It is likely that a larger sample would cause these data to regress toward the mean and thereby reduce the standard error and enhance the potential to observe a significant effect.

The feasibility of this intervention in community-based senior centers also has important implications for dissemination. The design of this study constitutes a pragmatic trial, and as such, the research question addressed whether the intervention worked under usual conditions (Glasgow, 2013). Traditional research designs are conducted under ideal conditions and therefore tilt the scale in favor of internal rather than external validity. As a result, intervention effect size is susceptible to diminish once the intervention is implemented under usual conditions. Because our pilot efficacy study was conducted within community settings using participants who were representative of older adults in those communities, we anticipate that the capacity for broad program dissemination will ultimately be enhanced (Prohaska, Smith-Ray, & Glasgow, 2012). Moreover, the intervention effects observed in this study are likely to be reflective of results expected if the program were to be disseminated.

This study was the first to our knowledge to examine the impact of cognitive training on mobility in Black older adults. At the beginning of this century, adults age 65+ accounted for 12.4% of the U.S. population, but this will increase to 19.6% by 2030 (Goulding, Rogers, & Smith, 2003). The distribution of minority older adults is also increasing. By 2030, 27.4% of adults ages 65 and older will be from racial minority groups, with 16.5% being African American, American Indian/Native Alaskan, or Asian/ Pacific Islander (Goulding et al., 2003). As new public health innovations emerge, it is critical that their impact is tested within diverse groups of older adults.

This study was not without limitations. First, the study was conducted within a relatively small sample ($N = 45$). After attrition, 36 participants completed baseline and posttest assessments. Despite the small sample size, we found significant improvements in mobility outcomes. However, a larger sample appears to be needed to detect significant differences in 10MDGS. Intervention participants were expected to exhibit significant improvements in all three measures of mobility, but this hypothesis was confirmed for two (balance and 10MGS) of the three outcomes. Future studies should measure both balance and gait speed under dual-task conditions and include a plan for examining the mechanisms underlying the association between cognition and mobility. Another limitation was our inability to measure

maintenance effects of the intervention. In order to improve the public health impact of the intervention, it will be necessary to understand whether improvements derived from the intervention are maintained over a longer period of time. Finally, the potential public health impact of this intervention pertains to fall prevention among older adults. The small sample size and very brief follow-up period prohibited us from observing a decrease in falls. For this reason, the primary mobility-related outcomes included proximal predictors of falls: balance and gait speed. In order to assess the effect of cognitive training on falls, it will be necessary to conduct the intervention with a larger group of participants over a longer period of time. As a next step, adequately powered randomized controlled trials are needed to address these issues.

This study presents a novel solution to a major public health problem by supporting the impact of cognitive training on mobility, as measured by balance and gait speed, in older adults. This evidence is critical to understanding whether strategies for reducing fall risk in cognitively intact older adults should begin to include cognitive training as one factor in a multifactorial approach.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Participant Characteristics at Baseline.

Characteristic	Total			Intervention			Control		
	<i>N</i> (%)	<i>M</i>	<i>SD</i>	<i>n</i> (%)	<i>M</i>	<i>SD</i>	<i>n</i> (%)	<i>M</i>	<i>SD</i>
Recruited/randomized	45			23 (51.1)			22 (48.9)		
Gender (female)	41 (91.1)			19 (82.6)			22 (100.0)		
Race/ethnicity (Black, non-Hispanic)	45 (100.0)			23 (100.0)			22 (100.0)		
Age		72.47	6.33		73.26	7.15		71.64	5.39
Years of education		15.00	2.17		14.64	2.11		15.35	2.23
10-m gait speed (seconds)		9.92	3.26		10.00	3.69		9.84	2.80
10-m distracted gait speed (seconds)		11.21	3.76		11.16	4.26		11.26	3.25
Berg Balance Scale (0 to 28)		24.75	3.21		24.77	3.02		24.73	3.47

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Table 2
 Output From ANOVA Models Assessing the Association Between Outcomes and Treatment Arm.

Measure	N	Control				Intervention				Cohen's <i>d</i>	F value	p value
		Baseline		10 Weeks		Baseline		10 Weeks				
		M	SD	M	SD	M	SD	M	SD			
Berg Balance Scale	18	24.73	3.47	24.67	4.13	24.77	3.02	24.81	4.85	-0.76	4.71	0.038
10-m gait speed (seconds)	16	9.84	2.80	9.64	2.70	10.00	3.69	8.73	3.14	0.92	6.57	0.016
10-m distracted gait (seconds)	15	11.26	3.25	10.57	3.75	11.16	4.26	9.99	3.13	0.17	0.20	0.659