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ORIGINAL ARTICLE

Assessing the Effects of Interpersonal and Intrapersonal Behavior Change Strategies on Physical Activity in Older Adults: a Factorial Experiment

Siobhan K McMahon, PhD, MPH, GNP-BC[1] · Beth Lewis, PhD[2] · J Michael Oakes, PhD[3] · Jean F Wyman, PhD, RN, GNP-BC, FAAN[1] · Weihua Guan, PhD[4] · Alexander J Rothman, PhD[5]

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Abstract

Background Little is known about which behavior change strategies motivate older adults to increase their physical activity.

Purpose The purpose of this study was to assess the relative effects of two sets of behavior change strategies to motivate increased physical activity among older adults: interpersonal and intrapersonal.

Methods Community-dwelling older adults (N = 102, mean age = 79) were randomized in a 2 × 2 factorial experiment to receive interpersonal (e.g., social support, friendly social comparison; no, yes) and /or intrapersonal (e.g., goal setting, barriers management; no, yes) behavior change strategies, combined with an evidence-based, physical activity protocol (Otago exercise program) and a physical activity monitor (Fitbit One™).

Results Based on monitor data, participants who received interpersonal strategies, compared to those who did not, increased their average minutes of total physical activity (light, moderate, vigorous) per week, immediately (p = .006) and 6 months (p = .048) post-intervention. Similar, increases were observed on measures of functional strength and balance, immediately (p = .012) and 6 months (p = .003) post-intervention. The intrapersonal strategies did not elicit a significant increase in physical activity or functional strength and balance.

Conclusions Findings suggest a set of interpersonally oriented behavior change strategies combined with an evidence-based physical activity protocol can elicit modest, but statistically and clinically significant, increases in older adults' physical activity and functional strength and balance.

Future research should replicate these findings and investigate the sustained quantity of physical activity elicited by these strategies and their impact on older adults' quality of life and falls.

Trial Registration The ClinicalTrials.gov registration identifier is NCT02433249.

Keywords Aged · Physical activity · Accidental falls · Behavioral intervention · Motivation · Factorial design · Multiphase optimization strategy

✉ Siobhan K McMahon
skmcmaho@umn.edu

Beth Lewis
blewis@umn.edu

J Michael Oakes
oakes007@umn.edu

Jean F Wyman
wyman002@umn.edu

Weihua Guan
wguan@umn.edu

Alexander J Rothman
rothm001@umn.edu

1 School of Nursing, University of Minnesota, 5-140 Weaver-Densford Hall, 308 Harvard Street SE, Minneapolis, MN 55455, USA

2 School of Kinesiology, Behavioral Aspects of Physical Activity, University of Minnesota, 209 Cooke Hall, 1900 University Avenue SE, Minneapolis 55455, USA

3 Division of Epidemiology and Community Health, University of Minnesota, School of Public Health, 1300 South Second Street Suite 300, Minneapolis, MN 55454, USA

4 Division of Biostatistics, University of Minnesota, School of Public Health, A443 Mayo Building, Minneapolis, MN 55455, USA

5 Department of Psychology, University of Minnesota, N321 Elliot Hall, 75 E River Rd, Minneapolis, MN 55455, USA

Introduction

Low levels of physical activity contribute to some of the most serious health challenges facing older adults today. For example, the leading cause of injurious death among older adults is falls [1]. Despite evidence that falls can be reduced with the regular practice of exercises and movements recommended in evidence-based physical activity guidelines, less than 12 % of older adults perform these on a regular basis [2] and fall rates have continued to increase [1]. One reason for this knowledge translation gap is that although the types and doses of physical activity to recommend are well known, less is known about the behavior change strategies that might motivate older adults to perform them [3–5]. Although several behavior change strategies are promising, research examining their effects is scarce and inconclusive. In this paper, we describe a factorial experiment testing the relative effects of two empirically and theoretically informed sets of behavior change strategies—interpersonal and intrapersonal—that have the potential to motivate older adults to engage in physical activity as recommended by evidence-based guidelines.

Age-related decreases in leg strength and balance are the most common causes of falls [6]. But these can be mitigated with the regular practice of leg-strengthening and balance-challenging exercises, augmented with walking and flexibility movement [7]. In fact, these four types of exercises and movements, encompassed in evidence-based physical activity guidelines for older adults [8, 9], have been integrated into physical activity protocols such as the Otago Exercise Program [10] and Senior Fitness and Prevention [11]. Such protocols have been proven to be safe, relatively simple, and the most effective type of fall prevention intervention for older adults, including those with multiple chronic conditions and frailty [7]. However, their broad dissemination has not made an impact on older adults' physical activity behavior or health (e.g., fall rates).

Important content may be missing from existing evidence-based physical activity protocols and guidelines for older adults, which limits their impact. Although protocols specify the biomechanical aspects of exercises and movements, they do not provide guidance in how older adults might be motivated to integrate physical activity into their everyday lives [12]. In the field of fall prevention, factors that ensure "uptake" of and "adherence" to activities within interventions tested, such as behavior change strategies, have not been examined [7]. In the broader field of physical activity in older adults, meta-analyses of prior research results indicate that certain behavior change strategies such as "*barrier identification*" and "*problem-solving*" are associated with greater effects on physical activity than other strategies such as "*goal-setting*" [3–5]. Although these results are intriguing, the individual studies upon which they are based were designed to evaluate, on average, 7–10 strategies bundled together with other intervention components. This treatment package approach to evaluation limits our ability to delineate unique and joint effects of behavior change strategies, or sets thereof, used within interventions.

Prior research in this area is also limited by the fact that studies have primarily focused on the assessment of fall risk or occurrence, have relied on self-report measures when measuring physical activity, and have not captured follow-up data. Intervention research in the field of fall prevention has focused on the distal outcomes of fall risk and occurrence, not the proximal outcome of physical activity [12]. Assessing physical activity is warranted in this line of research because the ability of interventions to make an impact on distal health outcomes (e.g., falls) is dependent on their ability to increase physical activity. Thus, fundamental questions remain regarding if and how physical activity can be increased among older adults; questions that can serve as a starting point for also understanding how to increase specific exercises and movements encompassed within existing guidelines and protocols.

These types of questions warrant assessing parameters that reflect the quantity of physical activity over time (e.g., duration), which historically have been assessed using self-report measures [13]. However, self-report measures are associated with recall bias, which limits their precision [14, 15]. Objective measurements from physical activity monitors overcome these limitations and are now the preferred source of data for clinical research addressing questions related to the quantity of physical activity [13, 16]. Finally, assessing physical activity over time warrants measurements captured at several time points. Intervention research in the field of physical activity in older adults has primarily focused on pre- and post-intervention measurements, less on longer term follow-up measurements after intervention completion [17]. Such follow-up measures are critical for understanding if changes in physical activity are independently maintained or if they decay over time in the absence of a structured program [18].

The current study represents an important step in the process of developing an intervention that combines key behavior change strategies with an evidence-based physical activity protocol for older adults, Otago [19]. The first iteration of the intervention, piloted in prior research [20], was comprised of 10 behavior change strategies linked to wellness motivation theory (WMT) [21] plus the Otago protocol and a physical activity monitor. In preparation for this study, the behavior change strategies were separated into two sets, interpersonal (e.g., social comparison) and intrapersonal (e.g., goal development), based on empirical evidence and theory that suggest both sets have the potential to elicit increased physical activity among older adults, but in different ways [5, 22, 23]. Consistent with the multiphase optimization strategy (MOST) [24], separating these strategies into two sets enabled testing, through experimentation, their unique and joint effects [25]. The primary focus of this study is the effect of the intervention strategies on the quantity of physical activity as a primary outcome, assessed through objective and self-report measures, immediately and 6 months after the intervention. Functional strength and balance is also assessed as a secondary outcome to confirm that participants engage in the types of exercises and movements within Otago that target fall risk.

In sum, the overall purpose of this study was to assess the unique and joint effects of two sets of behavior change strategies, interpersonal and intrapersonal on older adults' physical activity, when combined with the core content of an evidence-based physical activity protocol and a physical activity monitor (Fig. 1). Our primary and secondary hypotheses were that community-dwelling older adults who receive each set of behavior change strategies, compared to those not receiving them, would (a) increase the quantity of their physical activity and (b) improve their functional strength and balance, immediately post-intervention and 6 months post-intervention. This research will yield valuable data to help guide the integration of effective behavior change strategies into evidence-based physical activity protocols for older adults.

Method

Design

Community-dwelling older adults ($N = 102$) participated in a 2 × 2 factorial experiment in which one factor was the receipt of a set of interpersonal behavior change strategies (no, yes) and the second factor was the receipt of a set of intrapersonal behavior change strategies (no, yes). Each participant was randomized to one of four conditions: (a) evidence-based physical activity protocol adapted for small groups (Otago) + physical activity monitor, (b) Otago + physical activity monitor + interpersonal strategies, (c) Otago + physical activity monitor + intrapersonal strategies, or (d) Otago + physical activity monitor + interpersonal strategies + intrapersonal strategies. Each participant attended eight weekly small group meetings (approximately 90 min each) with 4 to 6 other participants randomized to the same condition. The primary outcome was physical activity assessed via objective and self-report measures. The secondary outcome was functional strength and baseline. Participants were given thank you cards and $20 following each of the three data collection sessions. They were also invited to keep their physical activity monitors after the study. The Institutional Review Board at the University of Minnesota approved this study. The study's clinical trial registration is NCT02433249.

Participants

To be eligible for study participation, potential volunteers had to be ≥70 years old, speak English, have the ability to walk, not have a diagnosis of neurocognitive disorder(s) or a score of ≤21 on the telephone version of the Mini-Mental State Exam [26], and report physical activity levels that are below national recommendations for older adults. Specifically, participants were included who reported engaging in strength training less than two times per week and moderately intense aerobic activity less than 150 min per week [27]. Community-dwelling older adults were recruited via newspaper advertisements and fliers distributed in four neighborhoods of Minneapolis, Minnesota. Each neighborhood was in a different quadrant of the city and near one of the four host community centers. The advertisement for a "University of Minnesota Wellness and Physical Activity Study" invited people to apply who were interested in participating in small group meetings in a neighborhood community center to learn about and practice activities that maintain leg strength and balance.

Intervention

Meetings were hosted within four community centers that were easily accessible via public transportation and had health promotion goals that complimented the purpose of this study. Transportation was coordinated and funded upon participant request: 5 of the 102 participants made this request. Information about standardized delivery and intervention content that varied according to condition is summarized in Table 1. Each meeting included time to learn and practice movements according to the Otago physical activity protocol: 15 min during meeting 1 and gradually increasing to 60 min by meeting 8. Each meeting also included time to discuss topics according to assigned condition. Discussion topics

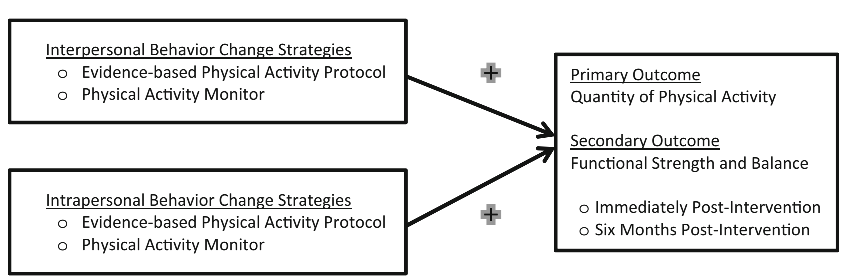


Fig. 1 Intervention conceptual model

Table 1 Intervention delivery strategies and content, by condition

Condition			
Otago Physical activity monitor	Otago Physical activity monitor Interpersonal BCS	Otago Physical activity monitor Intrapersonal BCS	Otago Physical activity monitor Interpersonal BCS Intrapersonal BCS
Intervention delivery			
•8 small group meetings	•8 small group meetings	•8 small group meetings	•8 small group meetings
•4–6 participants	•4–6 participants	•4–6 participants	•4–6 participants
•90 min/week	•90 min/week	•90 min/week	•90 min/week
•Fitbit One™	•Fitbit One™	•Fitbit One™	•Fitbit One™
•Intervention workbook	•Intervention workbook[a]	•Intervention workbook[a]	•Intervention workbook[a]
Intervention content			
•Otago physical activity protocol adapted for small group	•Otago physical activity protocol adapted for small group	•Otago physical activity protocol adapted for small group	•Otago physical activity protocol adapted for small group
•Discussion about aging and health	•Interpersonal BCS		•Interpersonal BCS
		•Intrapersonal BCS	•Intrapersonal BCS

BCS behavior change strategies, *Physical activity monitor* Fitbit One™

[a] Content includes illustrated instructions for fall-reducing physical activities, safety tips, by week; basic support focusing on Fitbit One™ devices; and content supporting inter and/or intrapersonal behavior change strategies

centered on aging and health such as nutrition, sleep, and foot health [28] in meetings of participants randomized to condition one, which did not include a set of behavior change strategies.

We minimized contamination across conditions using several tactics. First, we scheduled intervention meetings at different times so that participants in different conditions were not in the same physical space at any given time. Second, participant workbooks appeared identical on the exterior. Third, we asked participants to refrain from sharing their workbooks with study participants outside their small group, until after study completion. Finally, we provided the trained interventionist with manuals to guide her delivery of content specific to each condition and meeting.

Physical Activity Monitors Each participant, across conditions, received a commercially available physical activity monitor, Fitbit One™ (Fitbit Inc., San Francisco, CA, USA). We chose Fitbit One™ for this study because their displays are consistent with features important to older adults, such as real-time feedback in the form of actual steps and distance. Basic operational instructions for using the physical activity monitors (e.g., how to wear, charge, read displays) were introduced during the baseline data collection period, then reviewed and reinforced at and between intervention meetings, as needed.

Physical Activity Protocol The Otago physical activity protocol, adapted for small groups, was delivered across conditions during each small group meeting. The Otago protocol includes four types of exercises and movements: 5 leg-strengthening, 12 balance-challenging, 5 flexibility, and walking [10]. Per protocol, light and moderate intensity exercises and movements, consistent with national and international physical activity guidelines, were gradually introduced, demonstrated, individualized, and practiced within the small group settings over the 8-week intervention period. Daily walking was also encouraged, at a usual pace for up to 30 min (divided into 10 minute sessions if preferred) to increase physical capacity. Mastery to perform the physical activities independently, outside of the small group meetings, was facilitated via initial guidance for each exercise and movement, safe walking, as well as periodic check-ups. In addition to learning and practicing within the small group meetings and walking every day, participants were encouraged to practice the exercises and movements on their own twice per week between the intervention meetings and then three times per week after completing the intervention.

Interpersonal Behavior Change Strategies The five main interpersonal strategies required dialogue and exchange between group members about physical activity-related ideas, experiences, and knowledge to elicit individual change [29]. The first two strategies included facilitating discussions about increasing the give-and-take of social support for fall-reducing physical activity with important others and identifying one's self as a role model. The third strategy included problem-solving social and environmental barriers to physical activity. The fourth strategy was to facilitate the integration of physical activity into social routines, including the use of community resources. The fifth strategy was friendly, noncompetitive social comparisons of personal physical activity practices and data trends obtained from monitors [30]. Discussions addressing the first and fifth strategies included how to interpret data visualizations from the physical activity monitor, and the relevance of different trends observed between participants and important others, as well as within each participant over time.

Intrapersonal Behavior Change Strategies The five main intrapersonal behavior change strategies required didactic review of key concepts followed by individual reflection and discussion about how these concepts and tools apply to personal situations. The first strategy included facilitating the development of personally meaningful, realistic, and specific physical activity goals, based on personal patterns and trends. The second and third strategies included identifying what makes physical activity satisfying as well as identifying facilitators and barriers to being active and ways to manage these factors. The fourth and fifth strategies were to facilitate the integration of physical activity into personal routines and the development of anticipatory plans for coping with potential disruptions. Discussions addressing the first strategy included how to use self-tracking data, captured by a physical activity monitor, to inform decisions about personal goals and progress.

Measures

Self-reported demographic, fall risk [26], and clinical characteristics were measured at baseline. Outcomes were measured at all three time points. The primary outcome, quantity of physical activity (duration) across domains (e.g., leisure time, household chores), was assessed broadly, as the average weekly minutes of total physical activity (light, moderate, vigorous intensities) using objective and self-report measures. We chose this measure as our primary outcome because the Otago protocol promotes four types of light and moderately intense activities that can be practiced in structured or free-living contexts [10]. Also, many older adults prefer light over moderate or vigorous activities and there is growing evidence that even light intensity activities improve the health and well-being of older adults [31]. The secondary outcome, functional strength and balance, was assessed to confirm that increased physical activity included exercises and movements targeting fall risk. Measures of psychosocial constructs targeted by the intervention were also captured at all three time points but are not the focus of this report.

To assess the quantity of physical activity objectively, we calculated participants' average weekly minutes of total physical activity, captured by participants' Fitbit One™ confirmed with average daily step counts. Recent evidence suggests that the triaxial accelerometers and propriety algorithms within Fitbit One™ monitors provide accurate estimates of overall energy expenditure among adults as well as step count among older adults [32–36]. Correlations between objectively measured average weekly total physical activity and average daily step count at baseline, immediately post-intervention, and 6 months post-intervention were $r = .81$, $r = .81$, and $r = .80$, respectively. The Fitbit One™ automatically classified each minute of device wear time as sedentary or active—light, moderate ("fairly active"), or vigorous ("very active")—according to proprietary algorithms, which have been shown to be valid for the Fitbit One among young adults [34]. Similarly, the Fitbit One™ automatically counted steps, another broad parameter of physical assessment, to confirm estimates of average weekly minutes of total physical activity. All Fitbit One™ data was captured wirelessly via Fitabase—a research database used in this study to collect, store, manage, and analyze physical activity data [37].

To assess the quantity of physical activity via self-report, we used the Community Health Activities Model Program for Seniors (CHAMPS), a short-term recall questionnaire. This 50-item questionnaire yields information about the type, intensity, frequency, and duration of physical activity in which people have participated during a typical week, over the last 4 weeks [38]. Frequency and duration subscales have been shown to discriminate subpopulations and have sensitivity to changes post-intervention [39]. The summary CHAMPS score used in this study was average weekly minutes of total physical activity, including those categorized as light and moderate/vigorously intense [15, 38].

To assess participants' functional strength and balance, we used the Short Physical Performance Battery (SPPB). It is comprised of standing balance, walking speed, and repeated chair rises, each contributing 0–4 points to a total integer score ranging from 0 to 12. Higher scores indicate higher levels of functioning [12]. The gradient of resulting total scores is a valid reflection of the variation in physical function among older adult populations [40].

Procedures

The study was conducted between April 2014 and August 2015 in three waves: 16–40 participants per wave. Individuals interested in the study underwent telephone screening. If eligible, individuals were then invited to participate in a pre-intervention appointment during which they provided informed consent and were enrolled in the study.

Data collection at all three time points took place in two phases by trained research assistants (RAs). During the first phase, RAs conducted one-to-one interviews to collect data and provide operating instructions for the physical activity monitors, which included access to a resource telephone number for troubleshooting assistance. Participants were called 24–48 h after this first baseline data collection appointment to ensure any additional questions they had about the study or monitor were addressed. After using the monitor for approximately 1 week, the second phase of data collection began, which focused on capturing the objective physical activity data using methods consistent with procedures recommended by experts in this field [41]. Research assistants instructed participants to wear their physical activity monitors while awake for seven consecutive days, to remove monitors only for sleep or water-based activities, and to document the times and days on which they wore the monitors [41]. After 7–10 days, RAs met with participants to validate the number of days and time each participant wore their monitor by reviewing the participants' documentation and checking the data. Days on which participants did not wear the monitor, according to self-report logs and Fitbit data, and hours in which there were 60 consecutive minutes of *no* activity data were considered invalid.

Participants for whom screening revealed less than 3 days of wear time [42] were asked to wear the monitor again, for the next 7–10 days. This closely mirrors wear time validity methods used in studies that use nonconsumer physical activity monitoring devices (e.g., Actigraph GT3X). Average days worn at baseline, immediately post-intervention, and 6 months post-intervention were 6.10 (SD = 2.12), 6.59 (SD = 1.05), and 6.46 (SD = 1.03), respectively. Average hours worn per day at baseline, immediately post-intervention, and 6 weeks post-intervention were 13.01 (SD = 1.87), 13.86 (SD = 1.09), and 13.45 (1.29), respectively.

After the second phase of baseline data collection was completed, randomization to one of four conditions was conducted using permuted blocks, 16–24 in size, according to enrollment wave and community center. Randomization schemes, generated electronically, were stored in an encrypted and secured electronic research file accessible but not editable by RAs. Research assistants used the schema to inform participants about the small group to which they were assigned, which also reflected the condition to which they were randomized. Because of the nature of the intervention and the logistics required to schedule small group meetings, RAs were not masked to randomization or small group assignments ($n = 20$). However, RAs did not participate in any of the small group intervention meetings.

The intervention was delivered by a board-certified gerontological nurse practitioner (primary author) trained in Otago and the behavior change strategies used in this intervention. Delivery and receipt of weekly objectives and activities were formatively assessed, reviewed, and discussed during regularly scheduled research team meetings to identify and correct drift from the intervention procedures [43].

Analyses

The primary aim of this study was to detect intervention effects on changes in the quantity of physical activity assessed immediately and 6 months post-intervention. Based on findings from prior research, we assumed a medium effect size (0.40) to estimate the sample size and then adjusted it based on anticipated 15 % attrition at 6 months. Thus, we estimated that a sample size 100 would enable us to detect medium effects of each set of behavior change strategies, as well as their interaction with 80 % power, under two-tailed hypothesis tests at a significance level of 0.05.

Data were analyzed using SPSS 22. Objective physical activity data was screened again for valid wear time: days on which participants did not wear the monitor and hours in which there were 60 consecutive minutes of no activity data were considered invalid and thus excluded from analysis. The quantity of physical activity was estimated by calculating the sum and average daily minutes categorized by the physical activity monitors (Fitbit One™), as active—including light, moderate, and vigorous intensities. The average valid minutes of physical activity per day were scaled to minutes per week, units consistent with the self-report measure in our study. Univariate analysis included descriptions of demographic, clinical, and outcome variables; attendance and attrition; by condition using means, standard deviations, and ranges for continuous variables; counts/percentages for categorical variables; and graphs for visualization. Bivariate analysis included between-group comparisons of baseline characteristics using analysis of variance (ANOVA) for continuous variables and chi-squared tests or Fischer's exact test for categorical variables. Spearman's rank correlation coefficients were calculated for average weekly total minutes of physical activity measured objectively and two other parameters: average total minutes of physical activity measured via self-report and average daily step count.

All enrolled participants, regardless of how many intervention meetings they attended, were included in the analyses. Two participants, who withdrew from the study, completed only a portion of the baseline physical activity measures and were therefore not included in multivariate analyses. Also, participants who were lost to follow-up or had missing follow-up data, immediately or 6 months post intervention, were not included in the multivariate analyses because this number was small and not differential by condition (see "Results") [44]. We also analyzed physical activity outcomes using intent to treat principles, by imputing worst-case values based on the assumption that participants who withdrew or did not complete follow-up physical activity measures, had declining conditions, or decreased physical activity. This carryforward approach procedure is considered to be very conservative [44, 45]. Complete case analysis and imputing worst-case values produced equivalent results; therefore, results from the complete case analyses are included in this report.

Prior to multivariate analysis, checks were conducted to ensure that there were no egregious violations of normality, linearity, homogeneity of variances, or homogeneity of regression slopes. Because this intervention was delivered in small groups (n = 20), we assessed whether there were similarities between members within each small group. Interclass correlations were calculated using variables that indicated small group membership and the quantity of physical activity at each measurement time point, which revealed baseline, immediately post-intervention, and 6 months post-intervention values of .005, .003, and .005, respectively. We also assessed effects of behavior change strategy sets and their interaction over time using General Estimating Equation (GEE) models, which enabled us to control for group membership. Results of these GEE models were equivalent to results from analyses of covariance (ANCOVA) models described in the following paragraph and reported in the "Results" section.

Main effects of the interpersonal and intrapersonal behavior change strategy sets on physical activity and their interaction immediately post-intervention and 6 months post-intervention were tested using 2 × 2 full factorial (ANCOVA) models. Independent variables were receipt of the interpersonal behavior change strategies (no, yes) and receipt of the intrapersonal behavior change strategies (no, yes). Dependent variables included physical activity measured objectively and via self-report, as well as SPPB; baseline values of each were used in respective ANCOVA models. Results were expressed using estimated marginal mean changes in outcomes by factor, all with corresponding SE. Cohen's d effect sizes were calculated with 95 % CI.

Results

The 102 community-dwelling older adults who enrolled in the study were primarily White (75 %), women (75 %) with at least some college education (70 %), and between the ages of 70 and 96 years (mean = 79, SD = 6.5). Differences in baseline demographic, fall risk, clinical characteristics, and physical activity were not statistically significant across conditions (see Tables 2 and 3). Retention rates immediately and 6 months post-intervention were 95 and 93 %, respectively. Data missing was due to participants who withdrew from the study or refused to provide physical activity data during at least one of the data collection periods. The number of participants with physical activity data missing from at least one time point was 11. Differences across conditions in missing or incomplete primary outcome data were not

Table 2 Baseline demographic characteristics, fall risk, chronic conditions, and attendance, by condition

	Otago protocol Physical activity monitor	Otago protocol Physical activity monitor Interpersonal BCS	Otago protocol Physical activity monitor Intrapersonal BCS	Otago protocol Physical activity monitor Interpersonal BCS Intrapersonal BCS	P
Number of participants	25	25	25	27	
Demographic variables					
Age: mean (SD)	78 (6)	79 (6)	80 (8)	78 (5)	.43
Female sex: n (%)	20 (80)	18 (72)	18 (72)	20 (77)	.90
African American: n (%)	5 (20)	5 (20)	8 (32)	7 (27)	.64
Caucasian: n (%)	20 (80)	20 (80)	17 (68)	19 (73)	.58
Education attainment—HS+: n (%)	20 (80)	16 (67)	20 (83)	17 (68)	.59
Fall risk and chronic conditions					
>2 falls in last year: n (%)	5 (20)	7 (28)	5 (20)	6 (23)	.94
Use of cane or walker: n (%)	9 (36)	6 (24)	7 (28)	9 (35)	.77
Heart: n (%)	8 (32)	8 (32)	7 (28)	10 (39)	.94
Diabetes: n (%)	6 (24)	7 (31)	7 (29)	8 (29)	.79
Lung: n (%)	2 (8)	3 (12)	1 (4)	4 (15)	.61
Arthritis: n (%)	19 (76)	13 (52)	15 (60)	22 (85)	.07
Intervention attendance (total of 8 meetings)					
Number of meetings: mean (SD)	6.9 (1.5)	7.1 (.8)	7.0 (1.3)	7.6 (1.5)	.12

BCS behavior change strategies, p represents differences in variables across conditions, using Fischer's exact test and χ^2 for categorical variables, one-way ANOVA for continuous variables statistically significant per Fischer's exact test, p = .644. There were no observable differences between participants who withdrew from the study, compared to those who completed the study. Figure 2 summarizes participant flow and retention.

Intervention Attendance

On average, participants attended 7.2 (SD = 1.4) out of the eight small group meetings. Attendance was not significantly different across conditions, $X^2(3) = 2.02$, $p = .12$ (see Table 2).

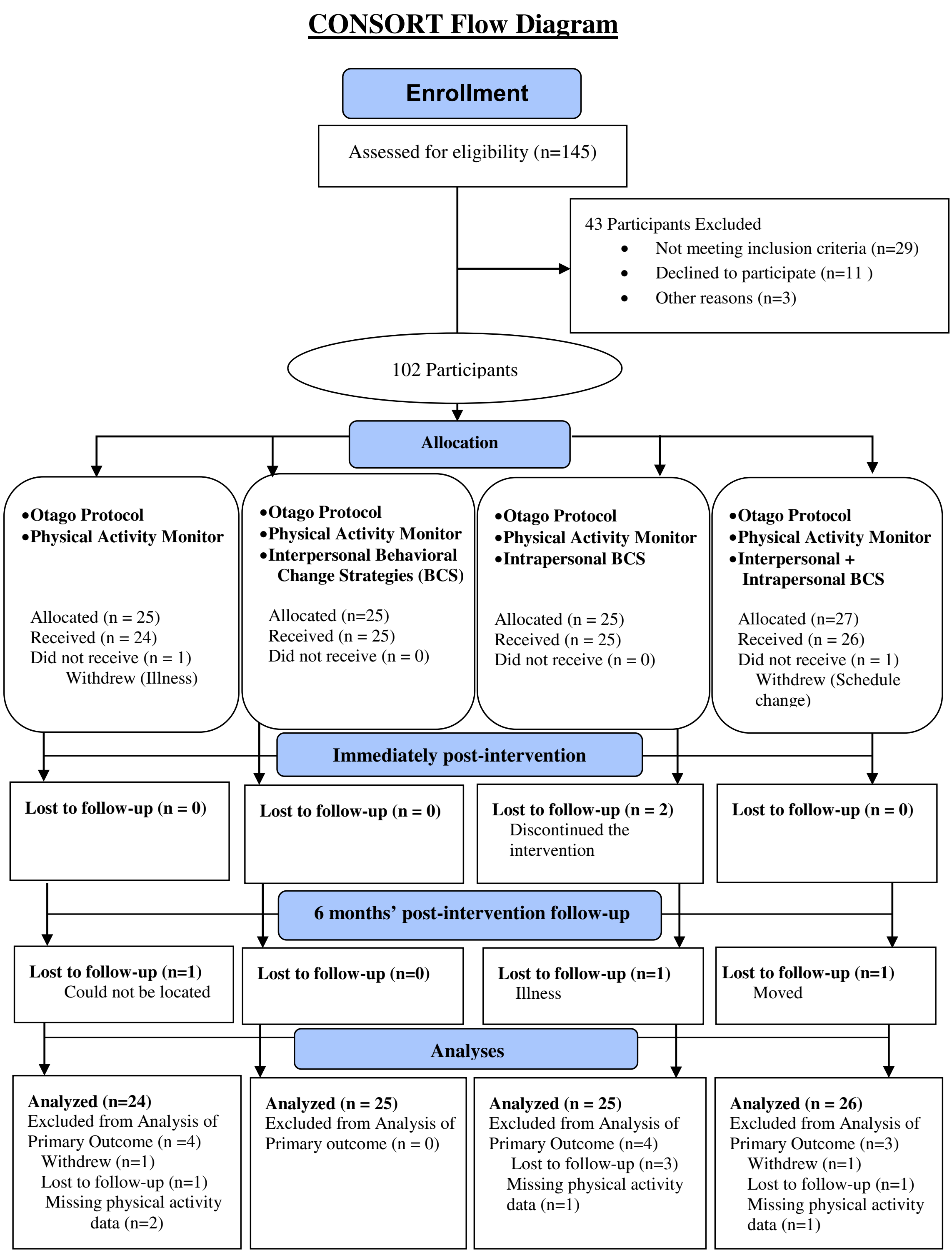


Fig. 2 Consort flow diagram

The most common reason for missing a meeting was acute illness or exacerbation of chronic illness, followed by competing social events and obligations.

Overall Changes in Physical Activity over Time

Overall, not controlling for condition, participants' average minutes of total physical activity increased over time according to (a) our objective measure, $F(1, 91) = 5.29$, $p = .02$, such that immediately post-intervention and 6 months post-intervention mean increases in average weekly minutes of total physical activity were 136 and 103 min, respectively, and (b) our self-report measure ($F(1, 95) = 11.71$, $p = .001$), such that immediately post-intervention and 6 months post-intervention increases in minutes were 181 and 358 min, respectively. Correlations between objective and self-report estimates of average weekly total physical activity (light, moderate, and vigorous intensities) at baseline, immediately post-intervention, and 6 months post-intervention were $r = .23$, $r = .20$, and $r = .18$, respectively.

Interpersonal and Intrapersonal Behavior Change Strategies: Effects on Physical Activity

Table 3 presents the unadjusted means of average weekly minutes of total physical activity, by condition. Results of ANCOVA models are summarized for the main effects and interactions of two sets of behavior change strategies, interpersonal and intrapersonal, on the quantity of total physical activity immediately and 6 months post-intervention, measured objectively (physical activity monitor) and via self-report (CHAMPS).

Objectively Measured Physical Activity Immediately Post-intervention Participants who received the interpersonal behavior change strategies increased their total physical activity immediately post-intervention more than those who had not received these strategies: mean difference = 189 min (SE = 71) per week, $F(1, 97) = 7.09$, $p = .006$ (see Fig. 3). Cohen's effect size for this effect was $d = 0.49$, 95 % CI [.08 to .89]. Participants who received intrapersonal behavior change strategies increased their physical activity 27 min (SE = 71) per week more than those who had not received these strategies, but this was neither substantively or statistically significant ($F(1, 97) = .05$, $p = .83$; $d = .17$, 95 % CI [−.22 to .57] (see Fig. 4). The interaction between the sets of interpersonal and intrapersonal behavior change strategies on objectively measured physical activity, immediately post-intervention, was not significant ($F(1, 97) = .99$, $p = .32$).

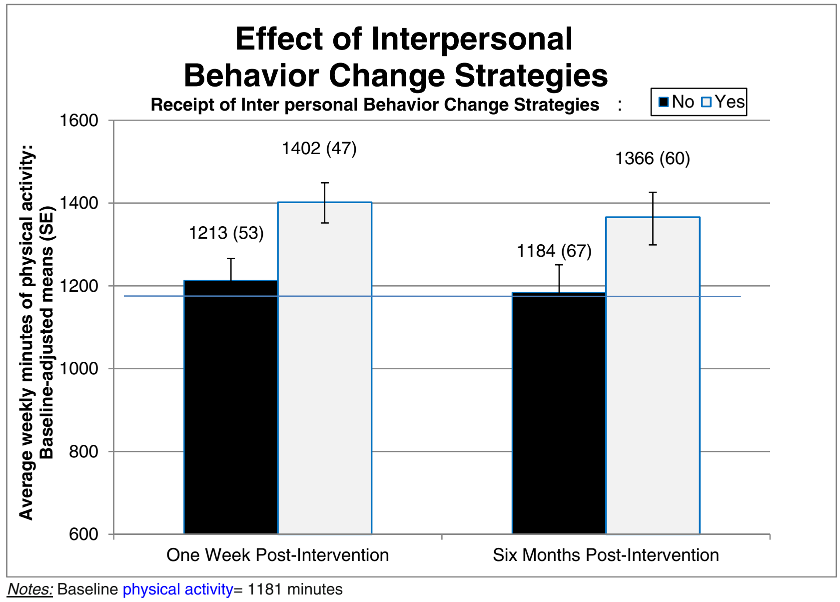
Objectively Measured Physical Activity 6 Months Post-intervention Participants who received interpersonal behavior change strategies increased their physical activity 6 months post-intervention more than did those who had not received these strategies: mean difference = 180 min (SE = 90) per week, $F(1, 91) = 4.03$, $p = .048$ (see Fig. 3). Cohen's effect size for this effect was $d = 0.36$ (95 % CI [.06 to .77]). Participants who received intrapersonal behavior change strategies increased their physical activity 97 min (SE = 91) per week more than did those who had not received these strategies, but again this difference was not statistically significant ($F(1, 91) = 1.15$ $p = .29$, $d = 0.01$, 95 % CI [−.40 to .42]) (see Fig. 4). The interaction between the sets of interpersonal and intrapersonal behavior change strategies on objectively measured physical activity, 6 months' post-intervention, was also not significant ($F(1, 91) = .30$, $p = .58$.

Table 3 Primary outcome: physical activity duration captured via physical activity monitor (Fitbit One^{TM}) and CHAMPS self-report questionnaire

Condition	Physical Activity Duration			
	Data source	Baseline	Immediately post-intervention Mean (SD)	6 months post-intervention
Otago protocol + physical activity monitor	*Physical activity monitor*	1212 (561)	1200 (530)	1193 (690)
	CHAMPS	2642 (1182)	2706 (1017)	2768 (1031)
Otago protocol + physical activity monitor + interpersonal BCS	*Physical activity monitor*	1204 (491)	1454 (756)	1321 (640)
	CHAMPS	2216 (855)	2409 (964)	2787 (1174)
Otago protocol + physical activity monitor + intrapersonal BCS	*Physical activity monitor*	988 (424)	1065 (528)	1069 (363)
	CHAMPS	1874 (1004)	2371 (919)	2680 (1235)
Otago protocol + physical activity monitor + interpersonal + intrapersonal BCS	*Physical activity monitor*	1182 (450)	1374 (529)	1448 (650)
	CHAMPS	2394 (729)	2509 (991)	2501 (955)

BCS behavior change strategies, *CHAMPS* Community Health Activities Model Program for Seniors physical activity questionnaire used to capture self-reported active minutes, *Physical Activity Duration* average minutes of total physical activity (sum of light, moderate, vigorous intensities)

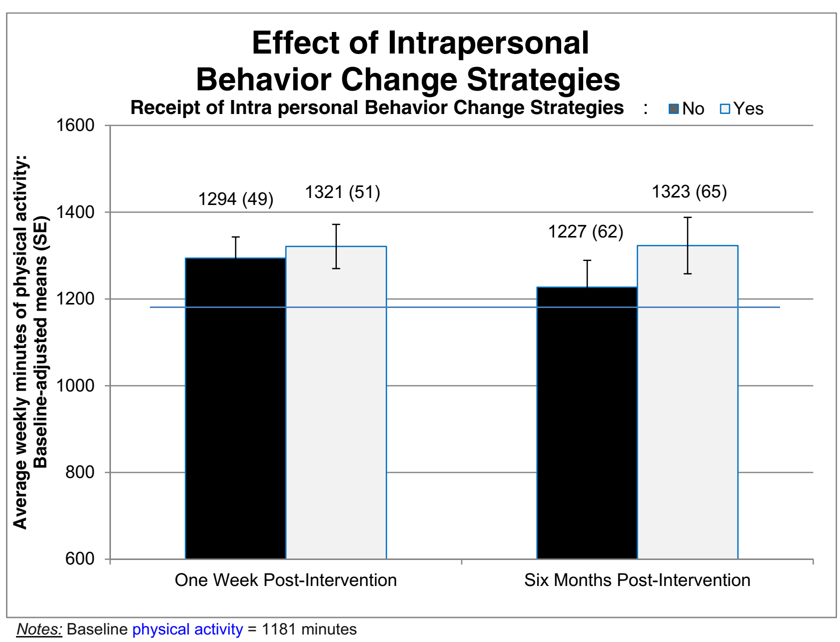
Fig. 3 Marginal means of interpersonal behavior change strategies on average weekly minutes of total physical activity (light, moderate, vigorous intensities) captured via physical activity monitor (Fitbit One™) immediately post-intervention and 6 months post-intervention



Self-Reported Physical Activity Immediately Post-intervention Immediately post-intervention, participants who received interpersonal behavior change strategies reported 41 fewer minutes (SE = 161) of physical activity per week than participants who had not received these strategies, but these differences were not significant (F (1, 97) = .06, p = .80. Similarly, participants who received intrapersonal behavior change strategies reported 15 fewer minutes (SE = 162) of physical activity per week, than participants who had not received these strategies, but these differences were not significant (F (1, 97) = .008, p = .93). The interaction between the sets of interpersonal and intrapersonal behavior change strategies on self-reported physical activity was also not significant (F (1, 97) = .07, p = .79).

Self-Reported Physical Activity 6 Months Post-intervention Participants who received interpersonal behavior change strategies reported 11 more minutes (SE = 200) of physical activity per week, 6 months post-intervention than participants who had not received these strategies, but these differences were not significant (F (1,

Fig. 4 Marginal means of the intrapersonal behavior change strategy set on average weekly minutes of total physical activity (light, moderate, vigorous intensities) captured via physical activity monitor (Fitbit One™) immediately post-intervention and 6 months post-intervention



95) = .003, p = .96). Participants who received intrapersonal behavior change strategies reported 125 fewer minutes (SE = 202) of physical activity per week than participants who had not received these strategies, but these differences were not significant (F (1, 95) = .38, p = .54). The interaction between the interpersonal and intrapersonal sets of behavior change strategies on self-reported physical activity was also not significant (F (1, 95) = 2.39, p = .13).

Interpersonal and Intrapersonal Behavior Change Strategies: Effects on Functional Strength and Balance Immediately and 6 Months Post-intervention

Table 4 presents the functional strength and balance assessment parameters (SPPB scores) by condition. Participants who received interpersonal behavior change strategies, compared to those who did not, showed significant increases in their SPPB immediately post-intervention (mean = .80; SE = .30), F (1, 97) = 6.9, p = .01 and 6 months post-intervention (mean = 1.11; SE = .36), F (1, 95) = 9.3, p = .003. However, participants who received intrapersonal behavior change strategies, compared to those who did not, showed no significant increases in SPPB immediately post-intervention (mean = 0.10; SE = .30), F (1, 97) = .12, p = .73 or 6 months post-intervention (mean = 0.07; SE = .37), F (1, 95) = .04, p = .85. The interaction between the interpersonal and intrapersonal sets of behavior change strategies on SPPB was also not significant at either time point.

Discussion

This is the first study to assess the unique and joint contributions of two distinct sets of behavior change strategies, interpersonal and intrapersonal intervention, on community-dwelling older adults' physical activity, when combined with core content of an evidence-based physical activity protocol and a physical activity monitor. The results revealed that participants who received interpersonal behavior change strategies increased their average minutes of total physical activity (light, moderate, and vigorous intensities), measured objectively, from baseline to immediately post-intervention approximately 3 hour per week more than participants who had not received these strategies. These increases in physical activity were maintained for up to 6 months post-intervention. However, the provision of intrapersonal behavior change strategies had no significant effect on the quantity of physical activity at either time point. Also, interactions between the interpersonal and intrapersonal behavior change strategies were not significant at either time point. Finally, although significant increases in self-reported physical activity were observed over time, there were no significant variations observed in these increases by condition, and correlations of the two types of physical assessment were positive but weak.

Findings suggest that interpersonally oriented behavior change strategies, in particular, can enhance the effects of an evidence-based physical activity protocol for older adults. Prior research examining the effects of such strategies on older adults' physical activity is mixed and limited to social support. A recent literature review designed to assess relationships between intervention behavior change strategies [4]—coded according to the CALO-RE behavior change technique taxonomy [46]—and physical activity outcomes concluded that *planning for social support* did not elicit increased physical activity. There are several possible explanations for the difference between our findings and those reported in this review. One is that intervention delivery in our study was to small groups, whereas the delivery in other studies may have been during individual coaching sessions. Another possible explanation is that we implemented interpersonal strategies beyond social support; specifically, we promoted friendly

Table 4 Secondary outcomes: functional balance and strength captured via total SPPB scores (0-12)

Condition	Total SPPB score (0–12)		
	Baseline	Immediately post-intervention Mean (SD)	6 months post-intervention
Otago protocol + physical activity monitor	8.5 (2.3)	8.8 (2.0)	8.6 (2.7)
Otago protocol + physical activity monitor + interpersonal BCS	8.6 (2.4)	9.0 (2.3)	9.1 (2.6)
Otago protocol + physical activity monitor + intrapersonal BCS	7.9 (2.2)	7.7 (2.8)	7.4 (3.4)
Otago protocol + physical activity monitor + interpersonal BCS + intrapersonal BCS	8.4 (2.5)	9.3 (2.0)	9.4 (2.3)

BCS behavior change strategies, *SPPB* Short Physical Performance Battery total scores ranging from 0 (no observed functional strength or balance) to 12 (no functional changes in strength and balance) noncompetitive *social comparison* as well as *group-based problem-solving of social and environmental barriers to physical activity.* Finally, it may be that results of the review were influenced by one or more of the common challenges associated with identifying active intervention ingredients in a compilation of randomized controlled trials designed to test the effects of intervention packages. These challenges include the overestimation of behavior change technique codes; confounding from other variables such as how well the intervention was delivered; and clustering effects, such that effective techniques combined with ineffective techniques may appear ineffective simply due to this joint delivery. Such challenges validate the need to examine strategies and sets thereof using experimental designs [3, 4].

Prior descriptive research also suggests older people prefer physical activity programs that offer opportunities to connect and interact with peers [47–49]. Such descriptions are congruent with socioemotional selectivity theory, which predicts that among older adults meaningful social connections are likely driven by goals that are emotionally satisfying such as the exchange of knowledge and expertise with peers in ways that enhance one's ability to maintain age-related gains, offset age-related declines, and enhance personal well-being [50]. Considering prior research, life span developmental theory, and our findings, it will be important to explore further if and how interpersonally oriented behavior change strategies motivate older adults' physical activity and the effects of these strategies on sustaining physical activity, fall occurrence, and the quality of life.

In this study, findings suggest that intrapersonally oriented behavior change strategies do not significantly increase the effects of an evidence-based physical activity protocol. Prior research evaluating intrapersonally oriented behavior change strategies that are similar to those used in this study show mixed results. For example, two recent interventions that integrated physical activity monitors with exercise prescriptions and counseling did not elicit increased physical activity in older adults [51, 52]. Conversely, recent literature reviews suggest that certain intrapersonally oriented strategies such as *barrier identification*, *problem-solving*, and *feedback* are associated with greater intervention effects on physical activity [4, 5]. Considering our results and prior research, there may be value in further pursuing hypotheses that certain intrapersonal behavior change strategies, delivered together with interpersonal behavior change strategies, help to sustain physical activity.

In summary, although both sets of behavior change strategies that are interpersonally and intrapersonally oriented have the potential to increase older adults' physical activity, in this study, only interpersonally oriented behavior change strategies yielded meaningful benefit. These results highlight the importance of experimentally evaluating the differential effects of behavior change content within evidence-based physical activity protocols. Results indicate that effects of meaningful magnitude may occur, by receipt of specific sets of behavior change strategies, effects that would not have been discernible had the factorial experimental design not been used [25]. If this study is replicated and extended to include follow-up times of 12 months or greater, as well as measures of falls and quality of life, findings will enable the selection of behavior change strategies to strengthen existing physical activity interventions designed for older adults. This approach is consistent with the MOST framework that guides the development of interventions to achieve the greatest public health benefit by ensuring they are effective, as well as efficient and sustainable [24, 25].

Consistent with prior research, results from objective and self-report measures in this study showed that 85 % of the physical activity performed by participants was light intensity [31, 53], and correlations between the measures were positive but weak [14, 15, 39, 54]. Although general public health goals are to increase older adults' minutes of moderate and vigorously intense physical activity, increasing minutes of light intensity activity also confers benefits [31, 55]. Most participants in this study reported physical activity quantities that were higher than what was measured objectively and reported increased physical activity post-intervention, compared to pre-intervention, regardless of condition assignment. This finding may reflect a limitation in the sensitivity of self-report measures to detect differences post-intervention between experimental conditions that all include a physical activity protocol. The sensitivity of CHAMPS has been demonstrated in prior studies comparing study participants exposed to a physical activity program versus a control group [38] but not in studies similar to ours, where all conditions include the same physical activity protocol. Also, our findings may reflect recall bias, such that participants either over- or underestimated the quantity of their physical activity [13, 15]. Findings that objective and self-report physical activity measures were weakly correlated confirm the importance of including objective measures in future intervention research and support ongoing efforts to advance the development of physical activity assessment strategies.

Objective measures of physical activity provided evidence that participants who received interpersonal behavior change strategies increased their total quantity of physical activity, confirmed with assessments of functional strength and balance. This approach addressed our fundamental question—if physical activity, as a proximal outcome, can be increased among older adults to make an impact on distal health outcomes (e.g., fall risk and occurrence). Our assumption, based on emerging evidence, is that the impact made by evidence-based protocols on distal health outcomes is dependent on their ability to increase physical activity. Results from prior research suggest physical activity of all intensities, practiced in structured or free-living contexts, benefits older adults [31, 55]. Measuring the quantity of total physical activity, confirmed with assessments of functional strength and balance, was a practical way to capture the participants' engagement in all four types of physical activity promoted and individualized by Otago, the evidence-based protocol used in this study.

The magnitudes of observed changes in total physical activity, as well as assessments of functional strength and balance measured (SPPB), were relatively small but clinically important. The increase in average daily step count among participants who received the set of interpersonal behavior change strategies was approximately 1000 steps, consistent with prior intervention research that suggests changes as small as 620 steps per day can be important [5]. The increase in average SPPB among participants who received the set of interpersonal change strategies ranged from 0.4 to 1.0, consistent with research that suggests changes in total SPPB scores ranging from 0.4 to 1.5 are clinically substantial [56].

Limitations

Our study has several limitations. First, the sample size, coupled with the large variability in the primary outcome of physical activity, limited the ability to make precise estimates of effect sizes and to detect small effects. Second, fall rates were not measured in this study. This study's small sample size and 6 month post-intervention follow-up period prohibited the accurate estimation of fall rates. In the future, it will be important to measure falls and confirm previous research findings that suggest increased physical activity is associated with reduced fall rates. Finally, the generalizability of our findings is limited, as the proportion of women participants was higher in our study than the US population, 75 versus 67 %, respectively, and the proportion of participants with college degrees was higher than in the US population, 46 versus 26 %, respectively [57].

Conclusion

Suboptimal physical activity levels among older adults contribute to significant public health problems, such as falls. Thus, it is essential to augment what is known—types and doses of physical activity recommended to improve the health of older adults—with what is not known—behavior change strategies that motivate older adults to increase their physical activity. This study demonstrates the feasibility of separating behavior change strategies into two distinct sets, representing two different ways of motivating people to take action: interpersonal and intrapersonal. Results suggest that receipt of interpersonal strategies, but not intrapersonal strategies, in combination with an evidence-based physical activity protocol and a monitor, can lead to increased physical activity among older adults for up to 6 months post-intervention. These findings provide initial evidence for the importance of interpersonal behavior change strategies to motivate older adults' physical activity. Future research should investigate the psychosocial processes through which increased physical activity occurs, if our findings are replicable, and whether interpersonal behavior change strategies—delivered singly or jointly with intrapersonal behavior change strategies—contribute to sustained physical activity (e.g., 12 months post-intervention), reduced falls, and quality of life.

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Authors' Statement of Conflict of Interest and Adherence to Ethical Standards Authors McMahon, Lewis, Oakes, Wyman, Guan, and Rothman declare that they have no conflict of interest. All procedures, including the informed consent process, were conducted in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

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