Published in final edited form as:

Cardiopulm Phys Ther J. 2020 October ; 31(4): 142–151. doi:10.1097/cpt.000000000000126.

Sit Less for Successful Aging Pilot Study: Feasibility of an Intervention to Reduce Sedentary Time in Older Adults in Independent Living Communities

Andrea L. Hergenroeder, PhD, PT,

University of Pittsburgh, Department of Physical Therapy, Phone (412)383-6964

Bethany Barone Gibbs, PhD,

University of Pittsburgh, Department of Health and Physical Activity, Phone (412)3834002

Mary P. Kotlarczyk, PhD,

University of Pittsburgh, Department of Geriatric Medicine, Phone (412)692-2481

Subashan Perera, PhD,

University of Pittsburgh, Department of Geriatric Medicine, Phone (412)692-2365

Tyler Quinn, MS,

University of Pittsburgh, Department of Health and Physical Activity, Phone (412)383-6530

Valerie Shuman, DPT,

University of Pittsburgh, Department of Physical Therapy, Phone (412)-624-7000

Jennifer S. Brach, PhD, PT,

University of Pittsburgh, Department of Physical Therapy, Phone (412)383-6533

Robert J. Kowalsky, PhD

University of Pittsburgh and Texas A&M University-Kingsville, Phone (361)953-2751

INTRODUCTION AND PURPOSE

Older adults are the least active group of Americans with national estimates of less than half achieving weekly physical activity recommendations.¹ Compounding this issue are growing concerns about prolonged sitting, or sedentary behavior. Sedentary behavior is defined as ‘waking activity expending <1.5 metabolic equivalents (METs) while in a seated, reclined, or lying posture’ and includes activities such as TV watching, reading, and computer use.² Emerging evidence has shown that, independent of physical activity, high levels of sedentary behavior are linked to adverse outcomes such as cardiovascular disease, diabetes, and mortality.^{3,4} Older adults are the most sedentary of age groups with a prevalence of sedentary time that is estimated to range from 8.5 to almost 10 hours per day.^{5,6} There is

Address correspondence to: Andrea L. Hergenroeder, PhD, PT, University of Pittsburgh, Department of Physical Therapy, Bridgeside Point 1, 100 Technology Drive, Pittsburgh, PA 15219, Phone (412)383-6964, alocke@pitt.edu.

Conflict of Interests

B. Barone Gibbs has received grant funding to her institution from the Humanscale Company

evidence that sedentary behavior is even higher (>11 hours/day) in those who reside in planned group residential settings compared to individuals in private homes.⁷

Sedentary behavior is shown to have a negative impact on physical function in older adults.^{8–11} In a cross-sectional study, older adults with less sedentary behavior and more breaks in prolonged sitting had better physical function after adjusting for moderate to vigorous activity.¹² Additional studies suggest that reduction in sedentary time is beneficial for physical function in older adults. In a study by Barone Gibbs, community-dwelling older adults were randomized to 12-week behavioral interventions that targeted decreased sedentary behavior or increased moderate to vigorous physical activity (MVPA). The sedentary behavior intervention promoted reduction of prolonged sitting through individualized counseling and an activity armband while the MVPA group received individualized counseling sessions to encourage participation in 150 minutes of moderate activity, such as brisk walking, per week. The sedentary behavior intervention led to improved physical function as measured by the Short Physical Performance Battery (SPPB) whereas the MVPA group did not show improvements in function.¹³

Chronic exposure to high amounts of sedentary behavior is also associated with poor cardiovascular health. In a large population sample of adults in Australia, increased sitting time was associated with increased cardiovascular risk including elevated systolic blood pressure and an 18% increase in risk for cardiovascular disease-related mortality with every hour increment in TV watching.¹⁴ Furthermore, studies suggest that replacement of sedentary time with light intensity activity benefits cardiovascular health.¹⁵ Buman et al found that for every 30 minutes that was reallocated from sedentary time to light physical activity, there was a 2–4% improvement in cardiovascular disease risk biomarkers.¹⁶ In addition, experimental studies support interrupting sedentary time with light activity breaks to improve blood pressure.¹⁷ For example, a laboratory study in adults with type 2 diabetes demonstrated that interrupting prolonged sitting (by 3 minutes every half hour) reduced blood pressure by 8–16 mm Hg compared to an uninterrupted sitting condition.¹⁸ The existing evidence supports that reductions in blood pressure are greater in older populations and those with prehypertension or overt hypertension.¹⁸

Physical activity is associated with improved mobility in older adults¹⁹ and reduced morbidity and mortality, especially from cardiovascular disease.^{20,21} Most studies have focused on adoption of structured moderate to vigorous intensity activity programs; however, uptake and adherence to moderate to vigorous guidelines is low, especially in inactive older adults and those with low physical function.²² Sedentary behavior, shown to consume most of the day for older adults and to have independent risk when accumulated in prolonged bouts, is an alternate behavior target that has potential for broader reach and long-term adherence. Despite this, there is a paucity of research that has examined interventions that have targeted sedentary behavior in older adults with lower levels of physical function who spend a large portion of the day in prolonged sitting.²³

Prior studies suggest that sedentary behavior interventions may benefit older adults in terms of physical function and cardiovascular health, however, there are several important gaps in knowledge. Previous studies have relied on self-reported sedentary time or the use of activity

monitors that are limited to measuring movement but not body position, both of which are subject to measurement error.²⁴ In addition, studies have not included residents of long-term care communities and those who have lower levels of physical function who may benefit the most from a sedentary behavior intervention. This is an important gap because it is likely that the physical and social environment in long-term care results in even more sedentary behavior and thus lower activity levels in residents.⁷ Finally, the feasibility and acceptability of a program that focuses on reduction of sedentary behavior has not been studied in this group. Prior to conducting a randomized trial, the feasibility of an intervention should be assessed.²⁵

The aims of the present pilot study were to: 1) assess the acceptability (participant satisfaction with the program) and the feasibility (session attendance, adverse events) of a sedentary behavior intervention, 2) examine the impact of a 12-week behavioral intervention on sedentary behavior (sedentary minutes, sit to stand transitions, time spent in sedentary bouts) and physical activity (steps per day) using objective activity monitors that are able to sense posture (i.e. sitting and standing), and, 3) examine the impact of the intervention on physical function, mobility and blood pressure. We hypothesized that the program would be acceptable and feasible in older adults, would lead to a reduction in sedentary behavior, and would lead to improvement in measures of physical function and mobility as well as a reduction in blood pressure.

METHODS

Study Design

This project utilized a 4-week, double-baseline assessment of sedentary time, physical activity, and health outcomes followed by a single group, pre- and post-intervention design, for residents in two independent living communities in the greater Pittsburgh area. The independent variable was the sedentary behavior intervention and the dependent variables were sedentary time (minutes), sit-to-stand transitions, and time spent in prolonged sedentary bouts (accumulated sedentary time in continuous bouts of >30 minutes and >60 minutes), physical function, mobility, and blood pressure. The University of Pittsburgh Institutional Review Board approved the study and all participants provided written informed consent prior to participation.

Participants and Recruitment

Informational sessions were held by the investigators at the independent living facilities and persons that expressed an interest in the study were met with individually to explain the study in greater detail. Block enrollment of study participants occurred in the Spring of 2017 to permit group participation in the intervention. To be included in the study, participants had to be 60 years of age or older, reside in an independent living facility, and be able to walk approximately 100 feet without the assistance of another person with or without an assistive device which was determined by observation of walking ability by the principal investigator of the study. Exclusion criteria were: inability to provide informed consent, presence of a comorbid medical condition that would limit ability to stand and perform light activity (e.g. recent orthopedic injury/surgery involving the lower extremities, currently

undergoing treatment for cancer, acute cardiovascular conditions), or presence of a skin condition that would prohibit the attachment of the activity monitor to the anterior aspect of the thigh (e.g. open wound or skin infection). Participants were also excluded if they required the assistance of another person to walk. The principal investigator met with each participant individually to review the consent form, explain study procedures, and answer any questions prior to obtaining informed consent. Each participant signed the consent form in person prior to participating in the study.

Twenty-four participants were recruited (n=18 at first baseline assessment and n=6 at second baseline assessment), assessed for eligibility, and provided written consent to participate in the study (age 82.4 ± 7.1 years, mean $\pm$ standard deviation). One participant dropped out of the study after the first week of intervention due to loss of interest, two participants were unable to participate in the final assessment due to health issues, and two participants experienced an issue with the activity monitor. As a result, 21 participants were included in the analyses of health outcomes and 19 participants were included in the analyses of physical activity outcomes (Figure 1).

Characteristics of the participants are listed in Table 1. Participants were predominantly female (71.4%) and white (100%) with a mean body mass index of 28.8 ± 4.8 kg/m². Participants had an average of four comorbid health conditions with the most common systems involved being musculoskeletal (90.5%), followed by vision/hearing (85.7%) and other general (i.e. sleep, pain) health conditions (61.9%). The average gait speed was 0.64 ± 0.24 m/s and 15 participants (71.4%) used an assistive device such as a wheeled walker or cane for walking. The majority reported a fall within the past year (57.1%) and most participants were fearful of falling (61.9%).

Procedures

An investigator (physical therapist or exercise physiologist) or research assistant (exercise physiologist) conducted in-person assessments for all outcomes at the participant's independent living community at 0 weeks (pre-intervention), 4 weeks (pre-intervention), and 16 weeks (post-intervention). After the 4-week pre-intervention assessment, individuals participated in a 12-week sedentary behavior intervention that was led by a physical therapist with training in behavioral interventions. Group sessions included behaviorally-based skill training including goal setting, problem solving, social support, modeling of behavior and relapse prevention. The strategies were modeled after constructs from Social Cognitive Theory,²⁶ Problem Solving Theory,²⁷ and the Theory of Planned Behavior²⁸ to promote behavior change and adherence.

The physical therapist met with the group of participants at the independent living facility on a set day and time each week. For each group session, the physical therapist followed a standardized meeting format that included recording attendance, targeted questions to facilitate participant discussion of progress towards weekly goals (10 minutes), presentation of a behavioral lesson that was led by the physical therapist (25 minutes), and an applied activity related to the weekly lesson (10 minutes). For the last 15 minutes of the group session, the physical therapist answered questions and met with participants individually, as needed. To ensure that all individuals in the study received the intervention materials,

participants were provided with the missed session materials and offered one-on-one discussion of the weekly topic in the event of an absence.

Intervention

The 12-week behavioral intervention targeted interruption of prolonged sitting by encouraging frequent activity breaks, such as standing or walking for a few minutes after sitting for more than 30 minutes. The intervention included the provision of a wrist-worn activity prompting device (UP wristband, Jawbone, San Francisco, California, USA) to encourage breaks from sitting, a pedometer (Accusplit AX2710 pedometer, Accusplit, Inc. Livermore, CA) to allow participants to self-monitor steps during activity breaks, and behavioral counseling during weekly group sessions. Study staff set the 'idle alert' of the wrist-worn activity prompter to vibrate after 30 minutes without movement during daytime hours; however, individual modifications were possible. While most participants opted to receive a 30-minute prompt from the UP wristband, some individuals preferred not to receive a prompt from the wristband as frequently and were provided with the option of utilizing an alternate strategy, such as setting a timer on their phone to alarm after 30 minutes of sitting.

During the group sessions, participants were provided with a study workbook that contained weekly lessons (Table 2) and the physical therapist discussed behavioral strategies to reduce sedentary behavior while assisting residents with setting realistic goals. In addition, the physical therapist utilized problem-solving techniques to address barriers for adoption of the behavior change, provided verbal and written feedback to participants on their goals, and monitored individual progress through the review of weekly diaries, which were used to self-monitor breaks from sitting. During the problem-solving exercise, participants were encouraged to describe any difficulties they encountered when trying to adopt the new behaviors in the previous week, brainstorm with the physical therapist and peers to identify potential solutions, identify the pros and cons of the solutions, and then select the best option to solve the problem. In the following week, participants were asked to provide feedback on the effectiveness of the solution. Participants were provided with a new activity diary each week which was reviewed by the physical therapist and returned to participants the following week with written comments about their behavior. The written comments reinforced participants' efforts and any progress towards changing their sitting behavior. The study targeted a reduction in total sedentary time of one hour by the final week of the intervention.

Measures to Describe the Sample

Participants were asked about demographics (age, gender, ethnicity, education level) and the presence of comorbid health conditions using the Duke Comorbidity Index.²⁹ Participants were also asked to report if they had experienced a fall within the past year and if they had a fear of falling by responding yes or no to the question "Are you fearful of falling?".

Outcomes

Acceptability of the Program.—Participants were invited to complete a 10-question survey after the 12-week intervention to assess acceptability of the program and evaluate

specific components of the program such as the activity prompter and the group session format.

Feasibility Measures (Attendance, Use of the Activity Monitor, Adverse Events)—Participant attendance in the weekly group sessions was recorded using a weekly sign-in sheet. To examine the feasibility of using the ActivPAL monitor, the number of device failures was monitored and the number of adverse events (skin irritation, etc.) related to monitor use were tracked. Adverse events related to the intervention were recorded.

Sedentary Behavior and Physical Activity.—Sedentary time (minutes), daily steps, sit-to-stand transitions, and time spent in prolonged sedentary bouts (accumulated sedentary time in continuous bouts of 30 and 60 minutes) were measured by the ActivPAL (ActivPAL, Glasgow, Scotland) activity monitor. This compact, thigh-mounted monitor was worn for a minimum of five days and a maximum of 7 days at each assessment period. The ActivPAL classifies an individual's free-living activity into time spent in sedentary, standing, and walking behaviors using proprietary algorithms and has been validated in older adults and individuals with lower physical functioning (Pruitt, 2008). Because of the unique wear location on the anterior thigh, this monitor is able to distinguish body position (e.g. reclining, sitting, standing) and is found to be a reliable and valid measure of sedentary and physical activity behaviors and step counts.^{30,31}

The key recommendations for use of ActivPAL in field-based research were followed for this study.³² Participants were asked to wear the activPAL physical activity monitor for a period of one week to measure sedentary time and ambulation during each assessment period (0, 4, 16 weeks). The device was contained in a waterproof nitrile sleeve and attached to the participant's thigh using Tegaderm, a transparent medical tape, per the instructions of the manufacturer. Monitors were applied and removed by research staff and participants were instructed not to remove the monitors during the assessment period (24-hour wear protocol).³² Participants were provided with a diary to record sleep and wake periods. Event data were downloaded and scored using participant diaries to remove reported sleep or non-wear intervals. Outcomes were summarized across valid wear days for each assessment in which the participant wore the monitor for at least 10 hours based on accepted protocols.³³ In the current research, the amount of sedentary behavior reduction that is required to confer health benefits is not clear.

Short Physical Performance Battery (SPPB).—This battery of performance-based measures was used to assess standing balance, gait speed and lower extremity strength (time to complete five chair rises). Composite scores were calculated for the SPPB with scores ranging from 0 (worst) to 12 (best) as per previously reported protocols.³⁴ This battery has been widely studied and has been shown to be a reliable and valid tool for use in older adults with a range of physical abilities.³⁵ Based on prior studies in older adults, a clinically meaningful change on the SPPB is 1.0 point.³⁶

Patient-Reported Outcomes Measurement Information System (PROMIS) Measures.—PROMIS Short Form instruments were used to measure the health-related constructs of physical function and mobility in this study. PROMIS short-form versions

contain a standard set of four to 10 questions for each domain and are scored using item-level calibration.^{32,37} For each measure, participant responses to questions were recorded and the HealthMeasures Scoring Service was used to generate a T-score for each measure (<http://www.healthmeasures.net/explore-measurement-systems/promis>). The T-score represents a standardized score with a mean of 50 (corresponding to the mean score in the US general population) and a standard deviation (SD) of 10.

PROMIS Physical Function Short Form 10a.—This self-report measure contains 10 questions that assess the ability to perform various activities that require physical capability. Activities range from self-care to more vigorous activities such as climbing stairs and participating in sports activities. This instrument has been found to be more responsive compared to other instruments such as the SF-36 physical function subscale and the Health Assessment Questionnaire Disability Index in older adults with moderate disability.³⁸ A higher score on the PROMIS Physical Function Short Form is indicative of better physical function.

PROMIS Mobility Measure.—This self-report measure has 15 questions used to assess mobility by asking the amount of difficulty one has performing a range of activities such as getting out of bed or a chair, standing without support, and going for a short walk (<15 minutes). A higher score on the PROMIS Mobility Measure indicates better mobility. The estimate of meaningful change on the PROMIS Mobility Measure has not been determined.

Resting Systolic and Diastolic Blood Pressure.—The appropriate cuff size for blood pressure measurements was determined by measuring mid-arm circumference using a tape measure according to the recommendations of the American Heart Association.³⁹ After a seated rest period of at least 10 minutes, blood pressure was obtained using the Omron HEM-705 (Omron Healthcare Inc, Kyoto, Japan) automated blood pressure machine once on each arm in successive order. A second measurement was repeated on the arm with the higher initial blood pressure. The two measurements taken on the same arm were recorded and averaged. A third measurement was taken if the first two differed by more than 10 mmHg for systolic blood pressure or 6 mmHg for diastolic blood pressure.

Data Analysis

Descriptive statistics were used to summarize physical activity, sedentary behavior, and health outcomes in the sample at the first baseline visit. Twelve-week changes in sedentary behavior, daily steps, physical function, and mobility were compared using paired *t* tests both between the first and second baseline assessments (to habituate participants to assessment procedures and to estimate changes over time without interventions) and from the second baseline to post-intervention (to estimate the intervention effect). ActivPAL data were adjusted for wear time so that standardized comparisons could be made for the activity measures taking into account that individuals had varying durations of daytime wear. Considering the pilot nature and small sample size of the study, we employed graphical techniques that consider individual changes in addition to averages similar to other pilot studies.⁴⁰ Pre-intervention to post-intervention individual changes in the outcome measures were calculated and plotted from the lowest to the highest baseline value for each participant

using needle plots. Our sample size of 21 participants was not based on statistical power to detect significant changes at a strict $\alpha=0.05$ level, rather what was feasible and appropriate for a pilot study based on time, effort, and budgetary restrictions, and similar to other pilot studies of non-pharmacologic interventions⁴¹ and similar outcomes that led to subsequent larger trials.⁴⁰

RESULTS

Change Over Time Pre-Intervention (0 – 4 weeks)

Analyses of the 0 to 4-week pre-intervention assessments revealed the measures were stable except for the SPPB which tended to decrease slightly during the 4-week baseline period (SPPB -0.4 ± 0.6 , $p=0.0140$) (Table 3).

All outcomes are reported for the pre-intervention (4-week) to post-intervention (16-week) timepoint.

Acceptability

The program evaluations revealed that participants were satisfied with the intervention with an average satisfaction rating of 4.7 ± 0.5 on a scale from 1 to 5 with 1 being very dissatisfied and 5 being very satisfied. For the individual components of the program, participants rated the weekly group sessions and the pedometer more favorably than the Jawbone Up activity prompter (4.2 ± 0.7 and 4.0 ± 1.3 vs. 2.9 ± 1.5). Participants reported that they were either “very likely” (70%, $n=14$) or “likely” (30%, $n=6$) to continue with strategies to reduce prolonged sitting behavior after the intervention was over.

Feasibility

Attendance in group sessions.—Weekly attendance in the group sessions was high with 85.7% ($n=18$) of participants attending all group sessions, 4.8% ($n=1$) attending most (75%) sessions, 4.8% ($n=1$) attending half of the sessions, and 4.8% ($n=1$) attending no group sessions. The participant that did not attend any sessions had caregiving responsibilities that precluded involvement in group sessions. Additional reasons for missing group sessions included illness and physician’s appointments.

Use of the ActivPAL monitor.—One activity monitor failure resulted in the inability to download physical activity data for one participant for the week 4 pre-intervention assessment. One participant was unable to wear the activity monitor because he was legally blind and as a result was unable to check his skin daily for irritation. For these reasons, activity data are not reported for these two individuals. There were no episodes of skin irritation in participants that wore the monitors during the study.

Adverse events related to the intervention.—No adverse events were reported during the study. Several participants experienced health issues that were deemed unrelated to the intervention but were able to continue with the study with a modification to individual goals.

Sedentary Behavior and Physical Activity

The data retrieved from the ActivPAL activity monitors and adjusted for wear time revealed a decrease in the number of sedentary minutes accumulated in 30-minute bouts (-27.7 ± 12.9 minutes/day, $p=0.0471$). The change in sedentary minutes, steps per day, and number of sit to stand transitions did not reach the .05 significance level (Table 4). The majority of participants (52.6%) decreased the number of sedentary minutes per day, increased the number of steps taken per day (78.9%), and increased the number of sit-to-stand transitions per day (72.2%) (Figure 2).

Physical Function, Mobility, and Blood Pressure

There was an improvement in both the performance-based measures of physical function (SPPB 1.5 ± 1.5 , $p=0.0001$, gait speed 0.06 ± 0.10 , $p=0.0230$) and self-report measures of physical function and mobility (PROMIS Physical Function 3.3 ± 5.3 , $p=0.0094$, PROMIS Mobility 2.7 ± 3.9 , $p=0.0046$) (Table 5). Twenty of the 21 participants (95.2%) had an improvement on the Short Physical Performance Battery (Figure 2). Systolic blood pressure was reduced by 7.8 ± 19.0 mmHg; however, this change did not reach statistical significance ($p=0.0760$). There were no changes in diastolic blood pressure.

DISCUSSION

The current study found that the intervention strategy of reducing sedentary behavior was feasible and acceptable among older adults in independent living communities, most of whom had lower levels of physical function, a history of falling, and multiple chronic comorbid health conditions. There were improvements in physical function and mobility despite minimal changes in sedentary behavior and physical activity measures after an intervention that targeted prolonged sitting in older adults. The magnitude of change on some the measures of physical function represents a clinically meaningful change based on prior studies in older adults which have identified a substantial change as 1.0 point on the Short Physical Performance Battery³⁶ and approximately 2 points for the PROMIS Physical Function Short Form.⁴² Though only total time spent in sedentary bouts lasting at least 30 minutes decreased significantly by about a half an hour after the intervention, these objective data suggest that participants were more likely to break up prolonged bouts of sitting.

The finding that small changes in sedentary behavior may be beneficial for health outcomes is supported in previous studies that have examined sedentary behavior interventions in adults³² and older adults.^{13,41} In a study of overweight and obese older adults, modest reductions in sitting time (<30 minutes) resulted in a significant improvement in gait speed and depressive symptoms.⁴¹ Additional studies have shown improvements in physical function and pain¹³ and cardiometabolic outcomes³² following a sedentary behavior intervention that resulted in a non-significant reduction in sedentary time. The current study adds to these findings through the identification of additional outcomes (i.e. mobility) that may be impacted through a reduction in sedentary time in older adults in independent living communities; however, the mechanisms by which improvements in these health outcomes occur remain unclear.

Our study target of a reduction in sedentary time of one hour per day was not achieved with our intervention strategy; however, the amount of time in bouts of prolonged sitting was reduced. While the American Heart Association and the current Physical Activity Guidelines for Americans support a reduction in prolonged sitting behavior, there are currently no specific public health guidelines for the recommended amounts or types of sedentary behavior.^{43,44} Research suggests changes in the patterns of sedentary behavior (i.e. reduction in long bouts of sitting and increasing sit-to-stand transitions) is an important target in addition to reduction of total sitting time.³

Our intervention strategy was feasible and acceptable for older adults, the majority of which had low levels of physical function based on the use of an assistive device (66.7%) and slower gait speed (mean gait speed=0.64 m/s). Because high levels of sedentary behavior are associated with poor physical function and worse cardiovascular health, physical therapists may consider targeting sedentary behavior as a part of physical activity programming. This may be particularly important for older adults who are shown to have the highest levels of sedentary behavior and individuals with disability who may be inactive and unable to engage in moderate to vigorous physical activity (>3 metabolic equivalents) such as brisk walking or biking.

In clinical practice, several methods can be employed to assess and track sedentary behavior such as brief questionnaires to identify total amounts of sedentary time, accelerometry, pedometers to track steps taken during breaks from sitting, or simple questions to identify prolonged bouts of sitting during the day.⁴⁵ Questionnaires are lower in cost and are able to assess the specific domains of sedentary behavior; however, this method is subject to measurement error and recall bias when compared to more objective measures. The use of objective measurement of sedentary behavior can reduce error and provide information about patterns of sitting behavior; however, there is higher cost and burden to the individual.⁴⁶ Given the pros and cons of each method, it is suggested that a combination of self-report and objective measures are used to measure sedentary behavior.

Specific intervention targets to reduce sedentary behavior may include interruption of prolonged bouts of sitting, the promotion of decreased total daytime sitting, and an increase light intensity activity, such as walking, during breaks from sitting. It is conceivable that the promotion of less sitting is an appropriate pre-cursor to engaging the patient in more light to moderate physical activities, as the patient progresses in their rehab course. The current intervention was focused on individual (goal setting and self-monitoring) and inter-personal (group sessions) levels of the socio-ecological model, both of which could be incorporated within rehabilitation practice settings (i.e. individual patient sessions or group exercise programs) similar to physical activity counseling.

This study presents preliminary evidence that a behavioral intervention targeting a reduction in sedentary behavior is acceptable and feasible for older adults residing in independent living communities. Despite this, we observed minimal changes in sedentary behavior and physical activity measures. A high percentage of participants attended all of the weekly group sessions during the 12-week intervention and the satisfaction with the intervention was high. We noted that shared aspects of the environment in the independent living

community allowed residents to support one another in changing behavior and participants often reported taking breaks from sitting as a group during seated recreational activities such as bingo and during mealtime. Our participants rated the weekly group sessions and the pedometers as the most helpful aspects of the intervention. While a few participants found the wrist-band prompter to be a helpful reminder for breaking up prolonged sitting bouts, the wrist-band was rated much lower than the other components of the intervention. Several participants reported receiving an 'idle alert' during ambulation if they were walking with a wheeled walker or rollator, which was viewed as a disincentive to wearing the wrist-band. This observation reinforces the need for the identification of additional strategies to reinforce breaks from prolonged sitting in older adults with mobility impairments, which may include alternative prompting devices and/or modifications to the physical environment.

Our study had several limitations. The entire study sample was white, so it is not clear if this intervention would be generalizable to a more diverse group of older adults. In addition, our study lacked a control group, which would have provided a comparison group for the dependent variables to assist with interpretation of study findings. In addition, the short-term follow-up period of three months did not allow us to evaluate the long-term effects of our intervention. Furthermore, we did not assess participants' baseline readiness for behavioral change, which could have confounded how each participant responded to the intervention. It would have been ideal to include a longer sampling period (>7 days) for measuring physical activity and sedentary behavior measures to allow for a better estimate of activity levels.

CONCLUSION

In conclusion, we found that a behavioral intervention targeting a reduction in sitting time was feasible and acceptable to older adults in independent living communities. Our intervention showed preliminary evidence for improvement in prolonged sitting, physical functioning, and mobility. Larger studies of multi-level sedentary behavior interventions in older adults with limited mobility and chronic health conditions are warranted.

Funding

This work was supported by University of Pittsburgh Claude E. Pepper Older Americans Independence Center (5P30 AG024827) and NIA K24 Midcareer Investigator Award in Translational Patient-Oriented Research in Aging (AG057728).

This study was approved by the University of Pittsburgh Institutional Review Board.

References

1. Keadle SK, McKinnon R, Graubard BI, Troiano RP. Prevalence and trends in physical activity among older adults in the United States: A comparison across three national surveys. *Prev Med* 2016;89:37–43. [PubMed: 27196146]
2. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *Int J Behav Nutr Phys Act* 2017;14:75. [PubMed: 28599680]
3. Diaz KM, Howard VJ, Hutto B, et al. Patterns of Sedentary Behavior and Mortality in U.S. Middle-Aged and Older Adults: A National Cohort Study. *Ann Intern Med* 2017;167:465–75. [PubMed: 28892811]

4. Dohrn IM, Kwak L, Oja P, Sjostrom M, Hagstromer M. Replacing sedentary time with physical activity: a 15-year follow-up of mortality in a national cohort. *Clin Epidemiol* 2018;10:179–86. [PubMed: 29416378]
5. Evenson KR, Buchner DM, Morland KB. Objective measurement of physical activity and sedentary behavior among US adults aged 60 years or older. *Prev Chronic Dis* 2012;9:E26. [PubMed: 22172193]
6. Harvey JA, Chastin SF, Skelton DA. Prevalence of sedentary behavior in older adults: a systematic review. *Int J Environ Res Public Health* 2013;10:6645–61. [PubMed: 24317382]
7. Brach JS, Almeida GJ, Perera S, Hergenroeder A, Kotlarczyk M, Gibbs BB. The Role of the Environment on Sedentary Behavior in Community-Dwelling Older Adults. *J Hous Elderly* 2019;33:31–40. [PubMed: 31073258]
8. Dogra S, Stathokostas L. Sedentary behavior and physical activity are independent predictors of successful aging in middle-aged and older adults. *J Aging Res* 2012;2012:190654. [PubMed: 22997579]
9. Gennuso KP, Gangnon RE, Matthews CE, Thraen-Borowski KM, Colbert LH. Sedentary behavior, physical activity, and markers of health in older adults. *Med Sci Sports Exerc* 2013;45:1493–500. [PubMed: 23475142]
10. Rosenberg DE, Bellettiere J, Gardiner PA, Villarreal VN, Crist K, Kerr J. Independent Associations Between Sedentary Behaviors and Mental, Cognitive, Physical, and Functional Health Among Older Adults in Retirement Communities. *J Gerontol A Biol Sci Med Sci* 2016;71:78–83. [PubMed: 26273024]
11. Santos DA, Silva AM, Baptista F, et al. Sedentary behavior and physical activity are independently related to functional fitness in older adults. *Exp Gerontol* 2012;47:908–12. [PubMed: 22884978]
12. Sardinha LB, Ekelund U, dos Santos L, Cyrino ES, Silva AM, Santos DA. Breaking-up sedentary time is associated with impairment in activities of daily living. *Exp Gerontol* 2015;72:57–62. [PubMed: 26385738]
13. Barone Gibbs B, Brach JS, Byard T, et al. Reducing Sedentary Behavior Versus Increasing Moderate-to-Vigorous Intensity Physical Activity in Older Adults. *J Aging Health* 2017;29:247–67. [PubMed: 26944808]
14. Rogerson MC, Le Grande MR, Dunstan DW, et al. Television Viewing Time and 13-year Mortality in Adults with Cardiovascular Disease: Data from the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Heart Lung Circ* 2016;25:829–36. [PubMed: 27262392]
15. Saunders TJ, Atkinson HF, Burr J, MacEwen B, Skeaff CM, Peddie MC. The Acute Metabolic and Vascular Impact of Interrupting Prolonged Sitting: A Systematic Review and Meta-Analysis. *Sports Med* 2018;48:2347–66. [PubMed: 30078066]
16. Buman MP, Winkler EA, Kurka JM, et al. Reallocating time to sleep, sedentary behaviors, or active behaviors: associations with cardiovascular disease risk biomarkers, NHANES 2005–2006. *Am J Epidemiol* 2014;179:323–34. [PubMed: 24318278]
17. Barone Gibbs B, Kowalsky RJ, Perdomo SJ, Taormina JM, Balzer JR, Jakicic JM. Effect of alternating standing and sitting on blood pressure and pulse wave velocity during a simulated workday in adults with overweight/obesity. *J Hypertens* 2017;35:2411–8. [PubMed: 28704258]
18. Dempsey PC, Sacre JW, Larsen RN, et al. Interrupting prolonged sitting with brief bouts of light walking or simple resistance activities reduces resting blood pressure and plasma noradrenaline in type 2 diabetes. *J Hypertens* 2016;34:2376–82. [PubMed: 27512975]
19. Pahor M, Guralnik JM, Ambrosius WT, et al. Effect of structured physical activity on prevention of major mobility disability in older adults: the LIFE study randomized clinical trial. *Jama* 2014;311:2387–96. [PubMed: 24866862]
20. Huai P, Xun H, Reilly KH, Wang Y, Ma W, Xi B. Physical activity and risk of hypertension: a meta-analysis of prospective cohort studies. *Hypertension* 2013;62:1021–6. [PubMed: 24082054]
21. Liu X, Zhang D, Liu Y, et al. Dose-Response Association Between Physical Activity and Incident Hypertension: A Systematic Review and Meta-Analysis of Cohort Studies. *Hypertension* 2017;69:813–20. [PubMed: 28348016]
22. Loprinzi PD, Sheffield J, Tyo BM, Fittipaldi-Wert J. Accelerometer-determined physical activity, mobility disability, and health. *Disabil Health J* 2014;7:419–25. [PubMed: 25224982]

23. Manini TM, Carr LJ, King AC, Marshall S, Robinson TN, Rejeski WJ. Interventions to reduce sedentary behavior. *Med Sci Sports Exerc* 2015;47:1306–10. [PubMed: 25222818]
24. Harvey JA, Chastin SF, Skelton DA. How Sedentary are Older People? A Systematic Review of the Amount of Sedentary Behavior. *J Aging Phys Act* 2015;23:471–87. [PubMed: 25387160]
25. Eldridge SM, Lancaster GA, Campbell MJ, et al. Defining Feasibility and Pilot Studies in Preparation for Randomised Controlled Trials: Development of a Conceptual Framework. *PLoS One* 2016;11:e0150205.
26. Bandura A Health promotion by social cognitive means. *Health Educ Behav* 2004;31:143–64. [PubMed: 15090118]
27. D’Zurilla TJ, Goldfried MR. Problem solving and behavior modification. *J Abnorm Psychol* 1971;78:107–26. [PubMed: 4938262]
28. Godin G, Kok G. The theory of planned behavior: a review of its applications to health-related behaviors. *Am J Health Promot* 1996;11:87–98. [PubMed: 10163601]
29. Rigler SK, Studenski S, Wallace D, Reker DM, Duncan PW. Co-morbidity adjustment for functional outcomes in community-dwelling older adults. *Clin Rehabil* 2002;16:420–8. [PubMed: 12061477]
30. Grant PM, Ryan CG, Tigbe WW, Granat MH. The validation of a novel activity monitor in the measurement of posture and motion during everyday activities. *Br J Sports Med* 2006;40:992–7. [PubMed: 16980531]
31. Ryan CG, Grant PM, Tigbe WW, Granat MH. The validity and reliability of a novel activity monitor as a measure of walking. *Br J Sports Med* 2006;40:779–84. [PubMed: 16825270]
32. Aadahl M, Linneberg A, Moller TC, et al. Motivational counseling to reduce sitting time: a community-based randomized controlled trial in adults. *Am J Prev Med* 2014;47:576–86. [PubMed: 25113139]
33. Edwardson CL, Winkler EAH, Bodicoat DH, et al. Considerations when using the activPAL monitor in field-based research with adult populations. *J Sport Health Sci* 2017;6:162–78. [PubMed: 30356601]
34. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol* 1994;49:M85–94. [PubMed: 8126356]
35. Freiburger E, de Vreede P, Schoene D, et al. Performance-based physical function in older community-dwelling persons: a systematic review of instruments. *Age Ageing* 2012;41:712–21. [PubMed: 22885845]
36. Perera S, Mody SH, Woodman RC, Studenski SA. Meaningful change and responsiveness in common physical performance measures in older adults. *J Am Geriatr Soc* 2006;54:743–9. [PubMed: 16696738]
37. Cella D, Riley W, Stone A, et al. The Patient-Reported Outcomes Measurement Information System (PROMIS) developed and tested its first wave of adult self-reported health outcome item banks: 2005–2008. *J Clin Epidemiol* 2010;63:1179–94. [PubMed: 20685078]
38. Fries JF, Krishnan E, Rose M, Lingala B, Bruce B. Improved responsiveness and reduced sample size requirements of PROMIS physical function scales with item response theory. *Arthritis Res Ther* 2011;13:R147. [PubMed: 21914216]
39. Pickering TG, Hall JE, Appel LJ, et al. Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Circulation* 2005;111:697–716. [PubMed: 15699287]
40. VanSwearingen JM, Perera S, Brach JS, Cham R, Rosano C, Studenski SA. A randomized trial of two forms of therapeutic activity to improve walking: effect on the energy cost of walking. *J Gerontol A Biol Sci Med Sci* 2009;64:1190–8. [PubMed: 19643842]
41. Rosenberg DE, Gell NM, Jones SM, et al. The Feasibility of Reducing Sitting Time in Overweight and Obese Older Adults. *Health Educ Behav* 2015;42:669–76. [PubMed: 25794518]
42. Lee AC, Driban JB, Price LL, Harvey WF, Rodday AM, Wang C. Responsiveness and Minimally Important Differences for 4 Patient-Reported Outcomes Measurement Information System Short

Forms: Physical Function, Pain Interference, Depression, and Anxiety in Knee Osteoarthritis. *J Pain* 2017;18:1096–110. [PubMed: 28501708]

43. Young DR, Hivert MF, Alhassan S, et al. Sedentary Behavior and Cardiovascular Morbidity and Mortality: A Science Advisory From the American Heart Association. *Circulation* 2016;134:e262–79. [PubMed: 27528691]
44. Piercy KL, Troiano RP, Ballard RM, et al. The Physical Activity Guidelines for Americans. *Jama* 2018;320:2020–8. [PubMed: 30418471]
45. Gibbs BB, Hergenroeder AL, Katzmarzyk PT, Lee IM, Jakicic JM. Definition, measurement, and health risks associated with sedentary behavior. *Med Sci Sports Exerc* 2015;47:1295–300. [PubMed: 25222816]
46. Healy GN, Clark BK, Winkler EA, Gardiner PA, Brown WJ, Matthews CE. Measurement of adults' sedentary time in population-based studies. *Am J Prev Med* 2011;41:216–27. [PubMed: 21767730]

Figure 1.
Study Flow Diagram

A Individual Changes in Sedentary Minutes/Day

B Individual Changes in Steps/Day

C Individual Changes in Sit to Stand Transitions

D Individual Changes in the Short Physical Performance Battery

Figure 2.
Individual Participant Needle Plots of Outcomes

Table 1

Participant Characteristics (n=21)

Characteristic	Mean±SD (Range) or n (%)
Age, years	82.4±7.1; (63–92)
Female	15 (71.4%)
Race	
White	21 (100%)
Education	
High school or less	10 (47.6%)
College	7 (33.3%)
Post-graduate	4 (19.1%)
Comorbid Conditions	
Number of comorbidities	4.0 ±1.6
Comorbidity Domains	
Cardiovascular	8 (38.1%)
Neurological	7 (33.3%)
Musculoskeletal	19 (90.5%)
General	13 (61.9%)
Visual/hearing	18 (85.7%)
Diabetes	6 (28.6%)
Cancer	5 (23.8%)
Lung	7 (33.3%)
Height (m)	1.6±0.1
Weight (kg)	76.0±14.2
Body mass index (kg/m ²)	28.8±4.8
Gait speed (m/s)	0.64±0.24
Assistive Device	
No device	6 (28.6%)
Cane	3 (14.3%)
Wheeled walker/Rollator	11 (52.4%)
Walking stick	1 (4.8%)
Fall history	
Fall in past year (% yes)	12 (57.1%)
Fearful of falling (% yes)	13 (61.9%)

Table 2:**Weekly Lesson Plan for Group Sessions**

Week 1	Sedentary Behavior and Health
Week 2	SMART Goal Setting and “My Activity Profile”
Week 3	Motivation -- What Motivates You?
Week 4	Problem Solving and Self-Monitoring of Behavior
Week 5	Social Support -- Your Social Network
Week 6	Sit Less and Step More
Week 7	Stand Up for Better Balance
Week 8	Your Environment and Taking Charge of What Is Around You
Week 9	Evaluating Your Progress
Week 10	Managing Stress
Week 11	Sit Less Refresher and Super Breaks
Week 12	Reflections and Ways to Stay Motivated

Table 3

Pre-intervention Changes in Outcomes (0 weeks to 4 weeks)

Outcome	Pre-Intervention (0 weeks)	Pre-Intervention (4 weeks)	Unadjusted Change (0 – 4 weeks)	Adjusted Change for Wear Time	p value
Sedentary Mins/Day	661.4±114.9	630.0±117.7	−31.4±60.6	−20.3±14.7	.1789
Sedentary Mins					
30-min bout	442.8±113.3	416.0±113.3	−26.8±70.9	−16.6±18.9	.3891
60-min bout	273.0±102.7	230.0±100.7	−42.2±75.4	−36.0±20.9	.0980
Steps/Day	5120.3±3345.4	4935.0±3283.7	−185.4±521.6	−62.8±215.0	.7725
Short Physical Performance Battery	6.5±2.9	6.06±3.0	−0.4±0.6*	--	.0140
Gait Speed (m/s)	0.63±.02	0.66±0.24	0.02±0.13	--	.4463
PROMIS Physical Function	39.6±7.3	40.4±6.6	0.81±3.4	--	.9426
PROMIS Mobility	38.5±5.5	37.8±4.9	−0.71±2.6	--	.6294
Blood Pressure					
Systolic BP	144.1±18.3	142.0±13.8	−3.1±13.8	--	.3883
Diastolic BP	71.3±8.1	69.0±7.6	−1.4±8.9	--	.5273

Table 4

Changes in Physical Activity Outcomes, n=19

Outcome	Pre-Intervention	Post-Intervention	Unadjusted Change	Adjusted Change for Wear Time	p value
Sedentary Minutes/Day	667.9±130.1	654.9±113.5	-13.0±90.4	-5.2±8.4	0.5441
Sedentary Minutes					
30-minute bout	475.2±152.0	440.7±135.0	-34.5±92.7	-27.7±12.9	0.0464
60-minute bout	310.75±181.0	283.1±142.4	-27.7±103.7	-22.6±20.0	0.2749
Steps/Day	4208.2±3234.5	4463.8±3064.6	255.6±729.9	270.6±171.9	0.1338
Number of Sit to Stand Transitions/Day ^a	39.3±12.5	42.3±11.8	3.0±8.1	3.1±1.9	0.1247

^a
n=18

Table 5

Changes in Physical Function, Mobility, and Blood Pressure, n=21

Outcome	Pre-Intervention	Post-Intervention	Change	p value
Short Physical Performance Battery	6.2±2.9	7.7±3.0	1.5±1.4	0.0001
Gait Speed (m/s)	0.64±0.24	0.70±0.25	0.06±0.10	0.0230
PROMIS Physical Function	40.4±6.9	43.8±7.4	3.3±5.3	0.0016
PROMIS Mobility	38.0±5.8	40.7±6.9	2.7±3.9	0.0400
Blood Pressure				
Systolic Blood Pressure	142.1±15.8	134.29±16.7	-7.8±19.0	0.0760
Diastolic Blood Pressure	70.1±8.2	70.1±8.8	0.0±9.2	0.9907