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Stand Up Now: A Sedentary Behavior Intervention in Older Adults of Moderate-to-Low Physical Function

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by

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ABSTRACT OF THE DISSERTATION

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Background: Sedentary behavior (SB) is associated with impaired physical function, frailty, falls, and higher mortality in older adults, the most sedentary age demographic in the US. There is limited research on the efficacy of interventions to reduce SB and improve physical function and mobility in older adults of moderate-to-low physical function.

Purpose: To examine the efficacy of a 12-week intervention, Stand Up Now (SUN), to reduce SB and improve physical function and mobility in older adults of moderate-to-low physical function in Continuing Care Retirement Communities (CCRCs).

***Methods*:** SUN was conducted in four CCRCs that were randomized to two intervention groups with different SB change goals: one group focused on reducing total sedentary time (SUN^{SL}) and one group focused on increasing sit-to-stand (STS) transitions (SUN^{STS}). Participants (N = 71; M_{age}=87±7yrs) in both SUN groups had weekly health coaching sessions over 12 weeks. SB,

physical function, and mobility were measured at baseline, 6, and 12 weeks via the activPAL, Short Physical Performance Battery (SPPB), and the 8-foot up-and-go (8ft UG), respectively. Linear Mixed Models (LMM) were used to examine the efficacy of SUN on activPAL measured variables (i.e., sitting, standing, STS transitions, stepping, and steps), physical function, and mobility at 6 and 12 weeks.

Results: Both SUN groups significantly decreased sedentary time (1.3±0.3hrs, $p<0.001$) and increased standing time (0.5±0.2hrs, $p<0.02$) at 6 weeks that was maintained at 12 weeks, compared to their baseline. SUN^{STS} significantly increased STS transitions at 6 weeks (5.4±4.1, $p<0.001$) while SUN^{SL} had no changes in STS transitions (0.5±3.1, $p>0.9$). No significant changes were noted in stepping time (0.04±0.08hrs, $p<0.15$) or steps (261±234, $p<0.14$) per day in either group. Both SUN groups improved physical function (SPPB) from baseline to 6 weeks (1.5±0.4 points, $p<0.001$) that was maintained at 12 weeks. No significant changes were seen in mobility for either group (0.5±1.5sec, $p>0.05$).

***Conclusions*:** SUN demonstrated the efficacy to improve SB and physical function in older adults of moderate-to-low physical function. Interventions targeting SB, such as SUN, are a promising strategy to improve physical function needed for activities of daily living and extend independence in older adults.

Introduction

The United States (U.S.) older adult age demographic (≥65yrs) will increase by more than 50% to 90 million people by 2060 and will make up nearly one-fourth of the U.S. population (Mather, Jacobson, & Pollard, 2015). Currently nearly 50% of older adults live with functional limitations in their activities of daily living (ADLs), leading to an increase in demand for caretakers as well as an increase in housing facilities that provide assistance. Simultaneously, older adults are the most inactive age group, spending > 65% of their awake time being sedentary (i.e., sitting or little to no movement) (Evenson, Buchner, & Morland, 2012). These rates are even higher for those in older adult living facilities, including Continuing Care Retirement Communities (CCRCs) (Davis et al., 2015; Reid et al., 2013; Rosenberg et al., 2016). Specific to older adults, sedentary behavior (SB) has been related to impaired physical function, frailty, falls, and higher risk of all-cause mortality (De Rezende, Rey, Matsudo, & Carmo, 2014; Dunlop et al., 2014; Gennuso et al., 2013; Santos et al., 2012; Wullems, Verschueren, Degens, Morse, & Onambele, 2016). Further, brief breaks from sitting ("sit-to-stand (STS) transitions") engage muscles, increase blood flow, and are associated with better physical function (Davis et al., 2016; Sardhina et al., 2014). Recently, the U.S. Department of Health and Human Services (DHHS) publically recognized the negative health effects of high amounts of SB and has added, "move more and sit less" to the updated 2018 Physical Activity Guidelines for Americans (PAGA) (US DHHS, 2018). Reducing SB, either through decreasing total sitting time or increasing number of breaks in sitting (i.e., STS transitions), has emerged as a critical public health priority.

Previous interventions have demonstrated short-term feasibility to reduce SB in older adults using feedback from a measurement device (i.e., activPAL) with health coaching strategies (Fitzsimmons et al., 2013; Gardiner, Eakin, Healy, & Owen, 2011; Kerr et al., 2016; Lewis et al.,

2016; Rosenberg et al., 2015). However, these studies were conducted in high functioning community-dwelling older adult samples with a focus on the feasibility of behavior change for this population to reduce SB. The longest study to demonstrate feasibility to reduce sedentary time lasted eight weeks (Rosenberg et al., 2015). Further, only two studies also measured physical function; while these two studies indicated improvements, there were suggested ceiling effects due to a high functioning sample (Gibbs et al., 2016; Rosenberg et al., 2015). Along with adding "sit less" to the 2018 PAGA, a recent *Sedentary Behavior Workshop* with experts in the field of physical activity and SB identified the need for interventions to target individuals across different living contexts and life phases (Manini et al., 2015). Also, given the current SB change interventions in older adults, a recent International Consensus Statement called for a need to test SB interventions in an assisted living setting (i.e., lower functioning older adults) and to test the effect of SB changes on geriatric-relevant health outcomes (e.g., physical function) (Dogra et al., 2017).

Thus far, SB interventions have not targeted lower functioning older adults. Therefore, a need exists to understand the acceptability and compliance of the current gold standard device for measuring SB, the activPAL, in this population. The activPAL device is an inclinometer mounted on the thigh via adhesive. It can be waterproofed and worn continuously to monitor behavior, measuring sitting/lying, standing, stepping, and changes in posture (e.g., STS transitions) (Edwardson et al., 2017). The activPAL is used both for measurement and as an intervention strategy to change behavior through individualized feedback (Fitzsimmons et al., 2013; Kerr et al., 2016; Lewis et al., 2016; Rosenberg et al., 2015).

Thus, the purpose of this study was to conduct Stand Up Now (SUN), a 12-week intervention designed for older adults of moderate-to-low physical function in CCRCs to reduce

SB, through either increasing STS transitions or reducing total sitting time, and improve physical function and mobility. SUN included behavior change techniques (BCTs) based on Social Cognitive Theory that have effectively changed SB in previous older adult interventions (Kerr et al., 2016; Rosenberg et al., 2015). To understand the efficacy of different SB change goals, we tested two intervention groups with different SB goals: SUN^{STS} (STS: sit-to-stand) focused on increasing sit-to-stand transitions and SUN^{SL} (SL: sit less) focused on reducing total sitting time throughout the day.

Study Aims and Hypotheses

The primary aims of Stand Up Now were two-fold: (1) to examine the the efficacy of the two intervention groups (SUN^{STS}, SUN^{SL}) to improve their respective SB goals (increase STS transitions or reduce sitting/increase standing) in older adults of moderate-to-low function at 6 and 12 weeks, and (2) to examine the efficacy of the two intervention groups (SUN^{STS}, SUN^{SL}) to improve physical function and mobility, as measured by the Short Physical Performance Battery (SPPB) and 8-foot up-and-go (8ft UG), respectively, in older adults of moderate-to-low function at 6 and 12 weeks. We hypothesized that both SUN groups would significantly improve their respective SB goals at 6 and 12 weeks compared to their baseline and to a greater extent than the other group, who would experience no changes. We also hypothesized that both SUN groups would significantly improve their physical function and mobility at 6 and 12 weeks compared to their baseline with no difference between intervention groups.

Our secondary aims included examining the efficacy SUN interventions (SUN^{STS}, SUN^{SL}) on other activPAL activity variables of stepping time and step count at 6 and 12 weeks. We hypothesized that both SUN groups would have no changes in their stepping time or step count from baseline. Also, we examined the efficacy of the two intervention groups (SUN^{STS}, SUN^{SL}) to

improve depressive symptoms in older adults of moderate-to-low function over 6 and 12 weeks. We hypothesized that both SUN groups would significantly improve their depressive symptoms at 6 and 12 weeks compared to their baseline with no difference between intervention groups. Our exploratory aims included examining the acceptability, compliance, and satisfaction of wearing the activPAL device with older adults of moderate-to-low physical function. We hypothesized that at least 80% of participants would provide at least four valid days of valid wear time (>10hrs/d), and would complete (> 75% completed log) device sleep/wake log, and indicate they would be willing to wear the device again. Lastly, we examined the acceptability and satisfaction of the SUN intervention components. We hypothesized that SUN participants in both groups (SUN^{STS}, SUN^{SL}) would rate intervention components above average (mean >3/5) with no differences between groups, as measured by a self-report satisfaction questionnaire.

SUN extends the current understanding of the efficacy of sedentary behavior change and its association with geriatric-relevant health outcomes in older adults of moderate-to-low physical function. Additionally, SUN contributes to the understanding of the compliance and acceptability of the gold standard sedentary behavior objective measurement device (i.e., activPAL) in this population.

Literature Review

Sedentary Behavior and Health

Sedentary behavior (i.e., sitting or little to no movement during waking hours) is among the leading causes of mortality in the US (Danaei et al., 2011). The adverse health effects associated with sedentary behavior (SB), particularly prolonged uninterrupted sitting, are widely reported through observational studies and retrospective data analysis in large cohort studies. Individuals with high levels of SB have a significantly higher risk of mortality and cardio-metabolic factors (e.g., waist circumference, body mass index (BMI), insulin resistance, cholesterol levels) compared with those who exhibited little SB, regardless of meeting physical activity (PA) guidelines (Chomistek et al., 2013; De Rezende et al., 2014; Katzmarzyk, 2010; Owen et al., 2010). In a meta-analysis by Ekelund et al., (2016) examined the sedentary and PA levels of over one million participants 18 to 90 years of age and found that a high amount of sedentary time was significantly associated with risk for all-cause mortality and metabolic risk factors for people with all PA levels, except for the highest activity level group, engaging in over 75 minutes of vigorous intensity PA per day (Ekelund et al., 2016). Further, Chau et al. (2013) conducted a meta-analysis in middle-aged and older adults, and reported that every hour of sedentary time is associated with a 2% higher risk of all-cause mortality and a 5% higher risk for those who are sedentary > 7hrs/day, while adjusting for PA level. Other short-term laboratory (ranging 1 to 7 days) interventions and animal studies have confirmed the adverse effects of prolonged sitting, even with designated bouts of vigorous PA (Chomistek et al., 2013; Duvivier et al., 2013; Hamilton, Hamilton, & Zderic, 2004). Further, laboratory studies have confirmed that short breaks (e.g., 1-minute break every 30 minutes) from sitting, regardless of intensity level (light or vigorous PA), resulted in significantly better blood glucose uptake, compared with taking no

breaks in sitting, in adults 40-75 years who had type II Diabetes Mellitus (Duvivier et al., 2013; Hamilton et al., 2004). There is much support that SB and PA are independently related to health outcomes. Thus, three countries have added a SB component to national PA recommendations prior to 2012 (British Heart Foundation, 2012). More recently, the U.S. added SB to the 2018 Physical Activity Guidelines for Americans (PAGA), released in November 2018 (US DHHS, 2018). The PAGA and other working groups of experts have recognized SB among the top research priorities and to examine strategies to reduce SB and improve the associated health effects (Manini et al., 2015; US DHHS, 2018).

Older Adults, Sedentary Behavior, and Health

While the U.S. population across all ages spends over 50% of their day sedentary, older adults (≥65yrs) are the most sedentary age group, spending >65% of their waking hours sedentary (Evenson et al., 2012; Matthews et al., 2008). Further, older adults are the largest growing age demographic in the US, projected to increase by more than 50% to 90 million people by 2060 (Mather et al., 2015). Currently, over 90% of older adults have at least one chronic disease and 77% have at least two, accounting for over $618 billion annually in Medicare spending (De Nardi et al., 2015; National Council on Aging (NCOA), 2016). While this age group is increasing in number and chronic conditions, it is also projected that the proportion of older adults who are dependent in their activities of daily living (ADLs) will rise from 22% in 2010 to 35% in 2030, leading to a substantial increase in the use of government-funded transition homes (Harris-Kojetin et al., 2013; Vincent et al., 2010). In 2010, an estimated $306 billion was spent on long-term care facilities. This amount will continue to rise given the current rates of increasing dependence (Harris-Kojetin et al., 2013). Loss of physical independence, most often due to a fall, is associated with lower quality of life (QOL), increased health care cost, and often leads to hospitalization and

an irreversible disability in ADLs (Boye et al., 2012; Convinsky et al., 2003; Guralnik, Alecxih, Branch, & Wiener, 2002; Hartholt et al., 2011). In 2012, older adults accounted for over 35% of hospitalizations with the highest average cost per stay at nearly $13,000, compared to all other age groups which averaged $10,400 per stay (Weiss & Elixhauser, 2014). Further, recent reports estimate older adult falls account for nearly $50 billion annually with the highest rates occurring in assisted living or residential care facilities, a setting where older adults who are nearly independent have access to partial assistance with their ADLs if needed (Florence et al., 2018; Harris-Kojetin et al., 2016). In a recent workshop, the Institutes of Medicine (IOM) reported that over 50% of older adults require long-term care services due to physical limitations in ADLs; thus, the IOM identified physical abilities as the most important research need to maximize independence and quality of life (IOM, 2016).

To accommodate the growing number of older adults and those who need assistance with ADLs, there has been a growth of Continuing Care Retirement Communities (CCRCs) (Senior Housing & Care Market, 2017; Zaren, 2010). CCRCs offer varying levels of care to accommodate end of life changes at the same living facility. While CCRCs often have a team of staff and a hired "activities director" to offer many opportunities for physical, social, spiritual, and mental activities, many barriers still exist for residents to participate in these programs regularly—such as motivation, fatigue, apathy, or disinterest (Bethancourt, Rosenberg, Beatty, & Arterburn, 2014). Research with older adults in living facilities supports lower levels of PA, higher levels of SB, as well as higher rates of falls than community-dwelling older adults (Chan et al., 2016; Harvey et al., 2015; Leung et al., 2017; Ried et al., 2013; Rosenberg et al., 2016). Also, studies with residents in older adult living facilities demonstrated that > 70% and > 12 waking hours of the day being sedentary (Chan et al., 2016; Harvey et al., 2015; Leung et al., 2017; Ried et al., 2013). Leung et

al. (2017) focused on older adults only in the assisted living level of the facility (i.e., lower functioning residents). They reported 87% of waking hours were sprent sedentary, which was also significantly associated with depression, physical function, and falls self-efficacy (Leung et al., 2017).

Cross-sectional studies in older adults repeatedly show associations between prolonged SB and indicators of not being able to maintain independence, including lower physical function, frailty, muscle quality, and sarcopenia, even after adjusting for PA level (Da Silva et al., 2017; Davis et al., 2014; Dunlop et al., 2014; Gennuso et al., 2013; Giandoudis, Bailey, & Daly, 2015; Mañas et al., 2017; Reid et al., 2018; Santos et al., 2012; Song et al., 2015). These rates are even higher in older adult living facilities with higher sedentary time, lower function, and higher rates of falls (Chan et al., 2017; Harris-Kojetin et al., 2016; Rosenberg et al., 2016). Using the Rikli and Jones (1999) Senior Fitness Battery, an objective measure of physical function, Santos et al., (2012) reported higher SB was associated with lower function for upper and lower body strength, mobility, and lower body flexibility, after adjusting for PA, gender, and age. Similarly, Seguin et al. (2012), reported significantly lower physical function, as measured by a self-reported measure (i.e., RAND SF-36) for those with > 6hrs/day of sedentary time compared with those ≤ 6hrs/day of sedentary time, after adjusting for PA. Two prospective studies reported higher rates of disability and frailty for those with higher amounts of SB (Da Silva et al., 2015; Song et al., 2015). A 12-year follow-up study reported 46% (OR= 1.46, 95% CI: 1.07 to 1.98) greater risk for disability in ADLs for each hour spent in SB, adjusting for PA (Dunlop et al., 2015). In a two-year follow-up, there was a 36% (HR = 1.36 per SB hour; 95% CI = 1.02 to 1.79) higher risk for frailty, as measured by a slow gait speed (< 0.6 meters per second (m/s)) or inability to stand from a chair, for each hour spent in SB after controlling for PA (Song et al., 2015). For older adults residing in

CCRCs, higher SB was associated with less objectively measured (i.e., SPPB) and self-reported (i.e., Late Life Disability) physical function, when accounting for moderate-to-vigorous PA (Rosenberg et al., 2016). For older adults in the assisted living level of a CCRC, SB was significantly associated with fear of falling, ADLs, and depression (Leung et al., 2015). While prolonged SB, regardless of PA level, is problematic to health of all individuals, for older adults, SB is repeatedly associated with functional limitations needed to maintain independence. Thus, with a growing older adult population that is highly sedentary, strategies to target SB to extend independence are needed.

Pre-Clinical Disability, Independence, and Older Adults

For older adults, prior to complete dependency, there is a time when they are still independent, yet functionally limited; this is an opportune time to intervene before a rapid decline to disability occurs (Fried et al., 1991; Manini, 2011). Extensive work by Fried et al. described older adult disability as similar to the "tip of the iceberg" (Fried et al., 1991; Fried, Bandeen-Roche, Chaves, & Johnson, 2000; Fried, 1996; Fried, Young, Rubin, & Bandeen-Roche, 2001; Wolinsky et al., 2005). Prior to a "visible" disability, there is a large measurable portion of disability indicators "under the water" where an intervention can delay disability, extend independence, and thereby optimize quality of life (QOL). This "under the water" phenomenon is known as "pre-clinical disability" (PCD), a term similar to a pre-clinical disease (e.g., pre-diabetes). PCD is identified when an individual modifies a task by either the mode (e.g., using a walker) or frequency (e.g., preparing meals less often) in which they complete the task. For example, an individual may use the handrail to walk up and down stairs or choose to take the elevator more often than before. As older adults live longer and the proportion of those living with

functional limitations increases, the number of those with PCD is an increasing Public Health concern (IOM, 2016; Vincent et al., 2010).

Independence, and the ability to age in place, is a priority for older adults. In a survey of over 800 seniors, 89% indicated that the ability to remain independent in one's home was very important, yet over half (53%) were concerned with their ability to do so. Also, seniors reported a fear of loss of independence more than death itself (Franklin & Hickie, 2011). The biopsychosocial model of Successful Aging by Anton et al. (2015) displays physical performance and mobility as the foundations of independence, which are best predicted through measures of physical function. This concept originated with Nagi's Model of Disability in the 1960's and was extended in 1991 by the Institutes of Medicine (IOM) to include QOL, showing that physical limitations leads to disability in socially defined roles which then impacts QOL (Brandt & Pope, 1997; Nagi, 1975). For older adults, the natural physiological decline in aging lead to functional limitations in ADLs and then less engagement in social interactions and roles, both associated with loss of independence and lower QOL (Doherty, 2009; Manini & Pahor, 2009; McAuley et al., 2006).

Thus, when PCD is identified, it is a crucial time to intervene to extend independence. Further, to accommodate the growing number of older adults, their health, and desire to age in place, CCRCs have a high number of older adults with PCD and related adverse health complications providing a strategic setting for SB interventions to delay dependency.

Physical Activity, Older Adults, and Health

It is well known that physical activity (PA) for all ages improves health and is associated with prevention of chronic diseases, higher QOL, and lower healthcare costs (Andreyenya & Strum, 2006; McAuley et al., 2006, Paterson & Washburn, 2010). For older adults, PA extends independence through decreasing fall risk, maintaining physical function, improving mobility

around one's environment, and improving cognitive performance (Chadzko-Zaik, 2013; Taylor et al., 2004). However, the Center for Disease Control and Prevention (CDC) reported that fewer than 20% of US older adults, per self-report, met the Physical Activity Guidelines for Americans (PAGA), compared to 48% of adults 18-64 years of age (CDC, 2013). When measured objectively with accelerometer devices, < 3% of older adults met the PAGA (Evenson et al., 2012, Matthews et al., 2008; Troiano et al., 2008). Low PA may be due to either lack of knowledge of the PAGA or lack of feasibility to achieve this level. For older adults with PCD, there are additional barriers to PA due to higher rates of arthritis and joint pain, lower energy levels, and higher fear of falling (Matthews et al., 2010). While PA research and several large funded interventions continue to target lower functioning (e.g., Lifestyle Interventions and Independence for Elderly (LIFE) Study; Pahor et al., 2014) older adults and those in CCRCs (e.g., Multi-level Intervention for Physical Activity in Retirement Communities (MIPARC); Kerr et al., 2012), evidence supports that prolonged bouts of SB, regardless of meeting the PA guidelines, is associated with all-cause mortality, metabolic risk factors, as well as geriatric-specific health outcomes such as physical function, depression, and fear of falling (Bauman, Chau, Ding & Bennie, 2013; Katzmarzyk, 2010; Owen et al., 2010). Thus, in addition to PA, SB interventions particularly designed to target SB in this population are needed.

Sedentary Behavior Change Patterns

Studies have examined various SB patterns and variables, such as bout length, total sedentary time, or breaks in sedentary time. Breaks in SB were associated with significantly better waist circumference, cholesterol, glucose, and all-cause mortality in overweight adults (45-65 years), when total activity throughout the day is constant (Dunstan et al., 2012). Additional cross-sectional studies in older adults (> 65 years), have also shown significantly better physical function

with more breaks in sedentary bouts (Chen et al., 2016; Gennuso et al., 2016; Lord et al., 2011). Although the optimal amount of time needed to reduce SB or increase number of breaks in SB for improved health is unknown, short-term laboratory studies in healthy adults (40-75 years) and animal studies have confirmed that a break every 30 minutes results in improved glucose and insulin levels, regardless of the activity intensity during the break (light or vigorous walking activity) (Duvivier et al., 2013; Hamilton et al., 2004). For older adults with a wide range of functioning levels, brief breaks from sitting (i.e., sit-to-stand (STS) transitions) expend little energy, but engage muscles, increase blood flow, and are related to improved physical function (Davis et al., 2014; Sardinha et al., 2015). Sardinha et al. (2015) reported that a greater number of breaks in SB were associated with a higher composite score of physical function, as measured objectively by the Senior Fitness Battery (Rikli & Jones, 1999), even after adjusting for total SB time and moderate-to-vigorous PA. However, older adults with PCD often use a walker, cannot stand up and sit down as comfortably, quickly, or frequently, and have higher joint pain and decreased lower body strength than higher functioning older adults that may impact their ability to reduce SB to improve function (Lorenz, 2009; Marco, Neville, Prince, & Ploutz-Snyder, 2012). Thus, it is unknown which sedentary behavior pattern is feasible or effective to improve health, increasing STS transitions or reducing total sitting time (i.e., standing for more time).

An intervention with two intervention groups targeted STS transitions or reduction in total sitting time in community-dwelling older adults over two weeks (Kerr et al., 2016). One intervention group focused only on increasing STS transitions and significantly increased STS transitions (i.e., added 13 STS/day), with no changes in total sitting time. The other group focused only on reducing total sitting time and significantly reduced sitting time (i.e., reduced 130 minutes/day), with no changes in STS transitions. This study demonstrated feasibility in SB change

when given a specific SB change goal in a high functioning older adult population over two weeks but did not measure a health outcome. There is much support from cross-sectional and prospective studies for the association between sedentary time and functional limitations in older adults that is distinct from PA. However, limited interventions have targeted older adults, and none have targeted older adults of lower functioning with a specific behavior change goal, a population and setting with a need to reduce SB.

Previous Sedentary Behavior Interventions Conducted with Older Adults

Due to the adverse health effects of SB, efforts have been made to reduce SB in the workplace and schools with standing desks and various forms of technology, yet few have specifically targeted older adults, the most sedentary age group (Barwais & Cuddihy, 2015; Carr et al., 2013; Hankonen et al., 2016). Older adults spend over 65% of their waking hours as sedentary and those without a spouse/partner spend over 10 hours a day alone and in social isolation (Evenson et al., 2012; Matthews et al., 2008; Shankar, McMunn, Banks, & Steptoe, 2011). Given that the majority of time for older adults is spent alone if they do not have a spouse/partner, community changes, public reminders, workplace changes that have successfully reduced SB in working adults or younger populations are ineffective for older adults (Hankonen et al., 2016; Shankar, McMunn, Banks, & Steptoe, 2011). Thus, interventions that have targeted older adults have used individual health coaching through in-person and phone call sessions.

Currently, six intervention studies have specifically targeted older adults (Fitzsimmons et al., 2013; Gardiner et al., 2011; Gibbs et al., 2016; Kerr et al., 2016; Lewis et al., 2016; Rosenberg et al., 2015). All have focused on feasibility to change SB, ranging from 1 day to 12 weeks with sample sizes ranging from 24 to 59 participants (59 people in the 1 day intervention study). Two of the studies used two intervention groups, while the others had one group with no control group

(Gibbs et al., 2016; Kerr et al., 2016). The intervention by Kerr et al. (2016) used two SB intervention groups (N = 36) and demonstrated that older adults can effectively either reduce total sedentary time (i.e., 130 minute/day reduction) or increase the number of sit-to-stand (STS) transitions (i.e., 13 STS/day increase) when the intervention targets one specific goal (i.e., either STS transitions or total SB time). However, when Rosenberg et al. (2015) gave their one group (N = 25) both goals together (reduce SB time and increase STS), they only significantly reduced total sitting time (i.e., 27 minutes/day reduction) and had no significant changes in STS transitions. Together, these studies support both strategies to change SB are feasible yet a distinct and clear goal must be communicated.

As previously noted, many older adults have a sedentary and typically isolated routine that requires interventions to target their unique lifestyle (Evenson et al., 2012; Matthews et al., 2008; Shankar, McMunn, Banks, & Steptoe, 2011). Previously effective interventions to reduce SB varied from a one day health coaching to eight weeks with various behavior change techniques (BCTs) from Social Cognitive Theory to coach individuals how to set goals, self-monitor, and increase motivation. All of these previous SB interventions indicated satisfaction with the intervention components, as measured by self-reported surveys and interviews at the end of the study, and feasibility to reduce SB. **Table 1** summarizes these previous interventions, the mode of intervention delivery, and the behavior change techniques (BCTs) that were used. The most common strategy was individualized visual feedback using the measurement device (i.e., activPAL). The one study that was 12 weeks and did not use feedback from the activPAL was the only study to not see objective changes in SB (Gibbs et al., 2016). However, this study used an armband to measure SB, which may not have been effective to detect SB changes due to the device placement. This study did report significant increases in step count (Gibbs et al., 2016). The

activPAL is considered the gold standard for measuring SB and permits health coaches to individually review when and how long the participant is sitting, standing, stepping, and completing STS transitions (Baumgartner, Jackson, Mahar, & Rowe, 2016). With this individualized graphical feedback, participants are able to discuss individualized strategies to reduce their SB.

Table 1. *Older Adult Sedentary Behavior Interventions & Behavior Change Strategies*

Study	Length	Mode	Intervention Strategies
Kerr, 2016 (n=36)	2 weeks	3 in-person	Goal setting, self-monitor, plan, signed goal contract, identify barriers, self-efficacy to meet goal, activPAL feedback
Rosenberg, 2015 (n=25)	8 weeks	5 phone calls (20-30min)	5 phone calls w/ health coach (20-30min); Motivational interview, confidence for goals set, barrier identification, mailed graphical feedback charts
Gibbs, 2016 (n=38)	12 weeks	4 in-person (45 min) + 8 phone calls (10 min)	Self-monitor each day with arm band; Goal-setting, and problem solving
Gardiner, 2011 (n=59)	1 day	1 in-person (45 min)	Self-efficacy, goal setting, self-monitoring, barrier identification; *4 workbook activities:* 1. Review of graphical data 2. Normative feedback w/ self-report sitting time and similar norms 3. Goal setting 4. Forming a plan
Fitzsimmons, 2013 (n=24)	2 weeks	1 in-person (45 min)	Graphical activPAL feedback; targeting BCTs; no specific goal

While interventions have demonstrated feasibility to reduce SB in older adults, participants were high-functioning community-dwelling older adults. Only two of the interventions also reported measures of physical function; both indicated improvements, yet lacked statistical significance due to a small sample size and high functioning population with probable ceiling effects (i.e., baseline physical function score of > 10.5 out of 12 points) in the measures (Gibbs et al., 2016; Rosenberg et al., 2015). Given the large number of older adults with functional limitations in their ADLs and additional barriers for implementing PA, there is a need to target lower-functioning older adults to reduce their SB and improve their health.

Given the current interventions with community-dwelling older adults and minimal report of health outcomes, a recent International Consensus Statement called for a need to target assisted (i.e., older adults across the mobility spectrum) living settings with SB interventions and to simultaneously measure geriatric-relevant health outcomes (e.g., physical function) (Dogra et al.,

2017). There is a need for a SB intervention to target older adults of moderate-to-low functioning with PCD and examine its effect on physical function in this population.

The activPAL: Sedentary Behavior Measurement and Intervention Tool

Improvements in technology have advanced the direct measurement of PA and SB. Accelerometer devices for PA have been developed for subjects to wear on different locations (e.g., hip, wrist) with the hip-worn Actigraph device recognized as the gold standard for PA for older adults (Matthews et al., 2012). However, the hip-worn device is a poor device to measure SB, as it cannot distinguish between standing and sitting and more specifically the breaks, or sit-to-stand transitions (An, Kim, & Lee, 2017; Koster et al., 2016; Pfister et al., 2017). Thus, the activPAL, a thigh-worn inclinometer, has emerged as the gold standard measurement for SB and has become a promising intervention tool to help behavior change with individualized visual feedback.

While much is known about the hip-worn accelerometer and best practices with compliance in many populations and age groups, less is understood about the activPAL, particularly with older adults (Matthews et al., 2012). The activPAL is mounted on the thigh via adhesive, can be waterproofed and worn continuously and it captures standing, sitting, stepping, and sit-to-stand (STS) transitions throughout the day. A strength of the activPAL is the ease of wearing during a 24-hr period because it can be waterproofed, worn continuously, and attached with little burden. A review by Edwardson et al., (2017) summarized protocols using the activPAL in over 50 studies. Most studies (71%) adopted the same wear time protocol as the hip-worn accelerometer, wearing for seven days with at least four valid days (>10hr/d), including one weekend day, considered a valid wear time. A previous study in older adults of lower physical function administered the device for seven full days and reported that 75.6% (n = 31) of their

sample provided enough valid days to be used in the analyses (Reid et al., 2013). The interventions in community-dwelling older adults of higher physical function showed 92% (N = 23) and 100% (N = 36) of their participants provided valid activPAL data (Kerr et al., 2016; Rosenberg et al., 2015). With the ease of the waterproofed, light weight, small size, this device may be an optimal direct measurement strategy for the lower functioning population.

Interventions in older adults using the activPAL also demonstrated the device as an effective intervention strategy to offer feedback, set goals, and make an action plan (Kerr et al., 2016; Rosenberg et al., 2015). Rosenberg et al. (2015) found that 100% (N = 25) of their participants ranked activPAL graphical feedback to be helpful (2/3 scale) or very helpful (3/3 scale) on their intervention satisfaction survey at the end of their study. However, it is unknown the compliance and acceptability of the activPAL to be used for measurement and as an intervention tool in a lower functioning population. Given the use of the activPAL as a measurement device and intervention tool, it is also important to determine the compliance and acceptability of this device in moderate-to-low functioning older adults.

Conclusions

When an individual has pre-clinical disability, it is a crucial time to intervene to extend independence. Research supports PA and SB are distinct behaviors and both independently influence health in older adults. While much research has focused on PA, little has been done to target SB in a population with pre-clinical disability. CCRCs also are growing in number and studies support higher levels of SB and lower levels of physical function in this setting, than in community-dwelling older adults. Further, there is much support of associations between high SB and poor health in older adults, however, few interventions have targeted this population or examined the efficacy of changes in SB on health outcomes. Thus, there is a need to fill the gap in

the literature and understand SB change strategies in older adults of lower physical function and the relationship to health outcomes of physical function and mobility. There is also a need to understand the compliance and acceptability of the objective SB measurement (i.e., activPAL) device in this population to use for measurement and as a behavior change tool.

Thus, the purpose of this study was to conduct a SB intervention in older adults of moderate-to-low physical function. This study was the first reported SB intervention in this population. It contributes to the current literature through understanding the compliance and acceptability of the gold standard SB measurement device, the activPAL, as a measurement and intervention tool. This study also contributes to the literature through understanding strategies to change SB with different specific SB goals of either increasing breaks in sitting (i.e., STS transitions) or decreasing total sitting time in older adults of moderate-to-low physical function. Finally, this study also contributes to the literature through understanding how changes in SB effect changes in the health of physical function and mobility in older adults, indicators of independence. This study provides a foundation for future research to build on to continue to fill the current gaps in the literature in this area.

Methods

Design and Setting

Stand Up Now (SUN) was an intervention study to examine the efficacy of a 12-week intervention (i.e., SUN) to reduce SB in older adults of moderate-to-low physical function, residing in Continuing Care Retirements Communities (CCRCs). SUN consisted of two intervention groups with different SB specific goals: one group focused on increasing sit-to-stand transitions (*STS*; SUN^{STS} Group); one group focused on reducing total sitting time (*SitLess;* SUN^{SL} Group) throughout the day. CCRCs all had comparable demographics and were matched on location and facility layout (i.e., campus style versus apartment) and then randomized to be either a SUN^{STS} or SUN^{SL} intervention site. Participants were measured at baseline, mid-intervention (6 weeks), and post-intervention (12 weeks).

Site Selection and Group Allocation

Sites were initially found and contacted through a web search by the Principal Investigator (PI) on CCRCs in San Diego County. After an initial phone conversation, an in-person meeting was arranged to outline the expectations for the site. Expectations included allowing participant recruitment and providing a space for health coaching sessions and study measurements. After site staff agreed to host the intervention, sites were matched and randomized to one of the two intervention arms.

After the web search, the PI made 13 initial phone calls. Eleven of the calls were answered or returned, which were then followed by in-person meetings with eight of the sites. From the eight in-person meetings, all site staff showed interest. However, two sites no longer returned contact via e-mail or phone after the in-person meeting and two sites initially agreed but paperwork with national management took longer than the study timeframe could allow. Thus, four sites were

matched on facility layout (i.e., campus style versus apartment) and location (i.e., North County vs. East County) and then randomized to one of the two different intervention arms (SUN^{STS}, SUN^{SL}). All four sites had more than 250 residents, an average age of ≥ 80 years, 70% female, and ≥90% Caucasian. ***Figure A1*** in Appendix A, shows the flow of site selection.

Participant Recruitment and Eligibility

Participants were recruited from the facilities by trained research assistants through flyers, social events, and announcements in the facility's bulletin. Interested residents were scheduled for an individual appointment where an interview-assisted screening with a research assistant took place to determine eligibility. Inclusion criteria were: (a) ≥ 60 years of age; (b) classified as moderate-or-low physical functioning (scoring ≤ 8, as measured by Short Physical Performance Battery (SPPB)); (c) able to stand up and move without a wheelchair for at least 10 feet (assisted devices, such as walkers, were allowed); (d) classified as "pre-clinically disabled" (PCD), based on reporting a compensation (i.e., frequency or mode) in at least one of the five primary movements and at least one of the seven ADLs outlined in Wolinsky et al., (2005); (e) does not currently and agrees not to attend more than one fitness class per week offered by the facility for the duration of the study; (f) able to understand and complete the informed consent in English and answer the appropriate "repeat back" questions. The "repeat back" method was used to assure the older adult understood what was being asked of them throughout the study and to screen for obvious cognition impairment. These criteria were based on the feasibility to carry out the study protocols safely.

We initially screened 83 older adults for eligibility and 71 (85.5%) were eligible and completed baseline measures. Ten of the ineligible participants were too high functioning (>8 SPPB score), one refused to wear the activPAL for the study, and one was unable to stand up

unassisted. Seventy-one, 60 (85%), and 58 (82%) participants competed baseline, 6-week and 12-week measurements, respectively. ***Figure 1*** is a detailed flow diagram of the participant screening, eligibility, and drop-outs throughout the study. Details broken down by site and group are in Appendix A (**Table A1**). Participants (N = 71), were an average of 86.8 years of age (Standard Deviation (SD) = 6.6), 82 % female, 90% Caucasian, 58% widowed, and 54% completed a college degree (**Table 2**). No significant differences were found between intervention groups (*ps* > 0.05) for demographic characteristics, except for length of residing at the facility ($p < 0.001$). There were also no differences between sites (*ps* > 0.05), except for age ($p < 0.007$) and length of residing at the facility ($p < 0.001$*)* (Appendix A; **Table A1**). For functional ability to complete primary movements, activities of daily living (ADLs), and instrumental activities of daily living (iADLs), participants indicated to modify (i.e., reduce frequency or alter the mode) or an inability to complete an average of 2.9 (SD = 1.2) of the five primary movements and an average of 5.6 (SD = 1.95) of the 12 movements incorporating primary movements, ADLs, and iADLs (**Table 3**). Approximately 50 % of participants modified how they stoop, climb stairs, or walk a half mile. We reported prevalence of modification or difficulty in **Table 4** for each item and the sum of modifications and difficulties for the three subcategories (i.e., primary movements, ADLs, iADLs) in **Table 3**. No significant differences were found between groups or sites for each item or the number of the modifications or difficulties (*ps* > 0.05) (Appendix A, **Table A2**). Each item and the sum of modifications and difficulties at mid-intervention and post-intervention are also reported in Appendix A (**Tables A2-A6**).

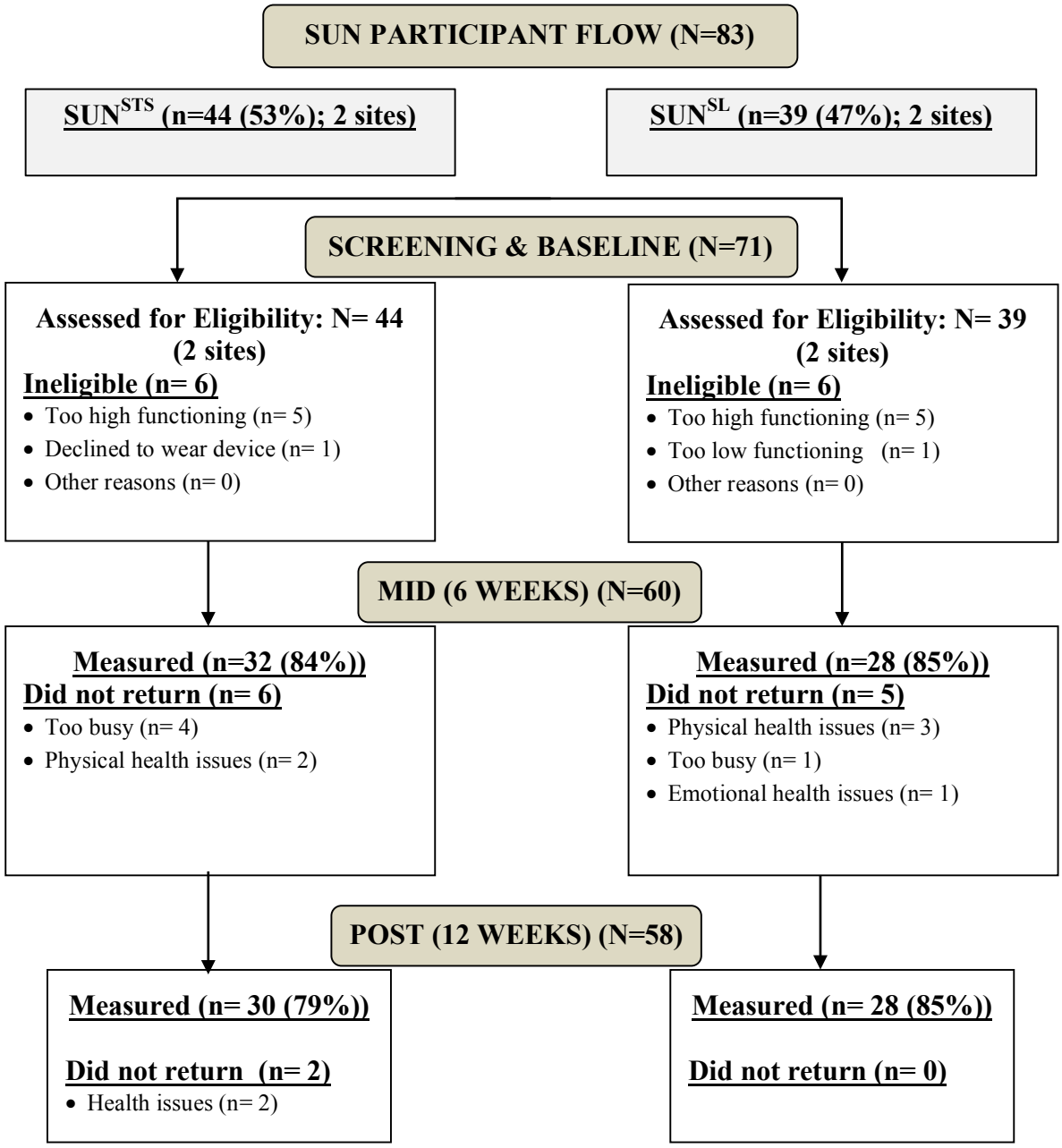


Figure 1. *Participant flow for eligibility, dropout, and measures.*

Table 2. *Baseline Descriptives of SUN Participants by Intervention Group*

	SUN^{STS} (N = 38)	SUN^{SL} (N=33)	TOTAL (N=71)	*p-value*
Age (yrs), Mean (SD)	86.7 (6.5)	86.8 (6.8)	86.8 (6.6)	0.97
Female (%)	84.2% (n=32)	78.8% (n=26)	81.7% (N=58)	0.556
Ethnicity*				0.573
Caucasian	89.5% (n=34)	90.9% (n=30)	90.1% (n=64)	
Hispanic	2.6% (n=1)		1.4% (n=1)	
Native American	7.9% (n=3)	6.1% (n=2)	7.0% (n=5)	
African American	2.6% (n=1)		1.4% (n=1)	
Other		3.0% (n=1)	1.4% (n=1)	
Education				0.085
High School	2.3% (n=10)	12.1% (n=4)	19.7% (n=14)	
Some College	34.2% (n=13)	18.2% (n=6)	26.8% (n= 19)	
Completed Bachelors	23.7% (n=9)	30.3% (n=10)	26.8% (n=19)	
Graduate School	15.8% (n=6)	39.4% (n=13)	26.8% (n=19)	
Marital Status				0.103
Widowed	65.8%(n=25)	48.5% (n=16)	57.7% (n=41)	
Married	7.9% (n=3)	27.3% (n=9)	16.9% (n=12)	
Single	7.9%(n=3)	15.2% (n=5)	11.3% (n=8)	
Divorced	15.8% (n=6)	6.1% (n=2)	11.3% (n=8)	
Other	2.6%(n=1)	3.0% (n=1)	2.8% (n=2)	
Time living in facility (years)	3.1 (2.8)	7.3 (.2)	5.0 (5.1)	<0.0001

Note. * can reflect higher than 100% due to mixed ethnicities; *p-value* = between group comparisons; Chi-Square tests used for categorical variables; independent t-tests used for continuous variables

Table 3. *Sum of Primary Movements, ADLs, and iADLs at Baseline*

Tasks	**SUN^{STS} (N = 38)**	**SUN^{SL} (N=33)**	**Total (N=71)**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**
Primary Movement Sum	2.52 (1.3)	2.90 (1.2)	2.70 (1.3)
ADL Sum	0.37 (0.75)	0.54 (0.97)	0.45 (0.8)
iADL Sum	2.30 (0.81)	2.20 (0.9)	2.30 (0.86)
Total	5.20 (1.9)	5.60 (1.95)	5.40 (2.1)

Note. Reference Table 4 for individual items; SD = Standard Deviation; ADL = Activities of Daily Living; iADL = instrumental ADL

Table 4. *Modification or Inability to Complete Tasks at Baseline*

Task:	Modification						Difficulty				
	SUN^{STS} (N=38)		SUN^{SL} (N=33)		Total (N=71)		SUN^{STS} (N=38)		SUN^{SL} (N=33)		Total (N=71)
Primary Movements:	N	%	N	%	N	%	N	%	N	%	N
1. Stoop, crouch, or kneel	22	58	11	33	33	46	10	26	16	48	26
2. Lift and carry 10lbs. (~a gallon of milk)	9	24	12	36	21	30	1	3	4	12	5
3. Go up and down 10 steps	21	55	14	42	35	49	3	8	9	27	12
4. Grasp or Handle (e.g. pick up a dime from a table)	3	8	2	6	5	7	2	5	0	0	2
5. Walking a 1/2 mile	18	47	19	58	37	52	7	18	8	24	15
ADLs											
1. Bathing	3	8	4	12	7	10	2	5	3	9	5
2. Dressing	2	5	3	9	5	7	1	3	1	3	2
3. Getting in and out of bed	6	16	7	21	13	18	0	0	0	0	0
iADLs											
1. Meal prep	29	76	19	58	48	68	3	8	7	21	10
2. Light housework (e.g. dishes)	16	42	5	15	21	30	1	3	3	9	4
3. Heavy housework (e.g. vacuum)	25	66	23	70	48	68	9	24	9	27	18
4. Managing Medications	6	16	3	9	9	13	0	0	2	6	2

Note. STS = Sit-To-Stand, SL = Sit Less; ADL = Activity of Daily Living; iADL = instrumental Activity of Daily Living

Theoretical Framework and Intervention

Stand Up Now (SUN) Intervention

SUN was a 12-week intervention designed to target an improvement in sedentary behavior (SB) either through increasing in sit-to-stand (SUN^{STS}) transitions or reducing total sitting time (SUN^{SL}). SUN was designed with behavior change techniques (BCT) based on Social Cognitive Theory (SCT) (Bandura, 2004). SCT includes three interrelated components (i.e., behavioral, personal cognitive, environmental) that influence behavior (Bandura, 2004). SCT was adapted from Social Learning Theory (SLT) in 1986 to emphasize the importance of the cognitive factors to influence behavior (Glantz, Rimer, & Viswanath, 2015). Increasing self-efficacy, a construct of

SCT, is a focus for many older adult interventions, as it has been consistently supported as a mediator for falls (Li, Fisher, Harmer & McAuley, 2005). We have included BCTs that have been shown to be most effective with action planning, motivation, goals, and social influences (Michie, 2008). The included BCTs have also been used in previous effective SB and PA interventions in older adults, including the CCRC setting (Gardiner et al., 2011; Hankonen et al., 2016; Kerr et al., 2012; Kerr et al., 2015; Rosenberg et al., 2016). Specific BCTs and how SUN targeted each BCT are described in **Table 5.** SUN health coaching sessions, phone calls, and distributed materials were adapted from previously effective interventions, with specific messages to target either an increase in STS transitions or a reduction in total sitting time throughout the day (Kerr et al., 2016; Kerr, 2017; Rosenberg et al., 2015).

Table 5. *Targeted Behavior Change Techniques (BCT)*

BCTs	SUN component
Goal setting	Goals set in counseling sessions to target STS transitions or sitting less
Graded tasks	Incremental goals each week
Self-monitoring	Tracking sheet
Plan/Implementation	Counseling session discussions and brainstorming
Prompts	Signage, bookmarks, magnets, water bottle
Information about behavior outcome	Discussions and education on health effects of sedentary time; Information in handouts
Feedback	Graphical feedback from activPAL

Note. STS: sit-to-stand; BCT: Behavior Change Techniques

The intervention health coaching sessions were designed to progressively "wean" the participant off the intervention by decreasing the contact time of in-person health coaching sessions and move towards phone call check-ins over the course of the 12 weeks. Health coaching sessions and phone calls decreased in length of time over the intervention. The first health coaching sessions (weeks 1 & 2) were approximately 60 minutes long. During the first week, the participants were also given the option to re-wear the activPAL to give immediate feedback at their next health

coach session (week 2). At the second health coach session, participants who wore the device again re-evaluated their behavior change with the activPAL feedback graphs based on the goals and action plan they completed at week 1. For those who did not wear the device, health coaches debriefed their experience with the goals they set and their perceptions of meeting those goals. After these first two sessions, participants did not wear the activPAL again until mid-intervention (week 6) and post-intervention (week 12) measures to reduce burden to the participant. Subsequent health coach sessions decreased in length (i.e., 40 minutes for weeks 3, 6, 7) and the last session (week 12) was a brief in-person check-in and distribution of the activPAL measurement device, lasting about 20 minutes. Phone call check-ins were approximately 20 minutes (weeks 4, 5) and then decreased to about 10 minutes (weeks 8, 9, 10, 11). Phone call sessions followed the same outline as in-person health coaching sessions (Appendix B). Each call included a debrief from the past week, a goal setting time, and ended with the participant indicating their importance and confidence level on a scale of 1 to 10 in their ability to complete their new goal. A visual representation of weeks for health coaching sessions, phone calls, and measurements is displayed in ***Figure 2.***

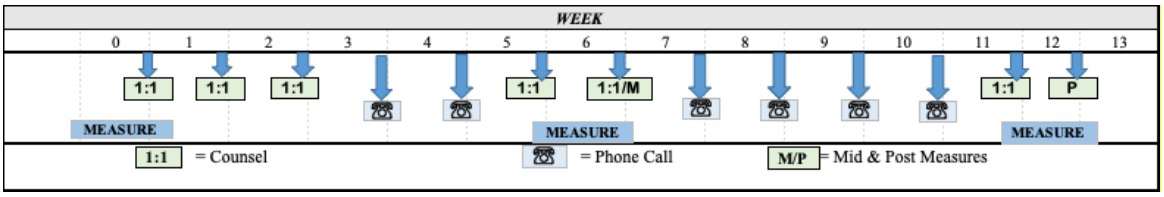


Figure 2. *Timeline for participant health coaching sessions and measurements.*

Intervention Fidelity

To maintain the fidelity of the intervention all health coaches were trained to follow the study script. There were different health coaches trained and assigned for each SUN (SUN^{STS}; SUN^{SL}) group. Each week, health coaches completed a "health coach record sheet" during the

sessions to assure all health coaching components were completed (i.e., activPAL graphical feedback (if applicable), goal setting, action planning, confidence and importance rating), as well as the length of each session and any adverse events. This detailed documentation allowed us to document the study attendance, length of sessions, and details during each session. Thus, each health coach was held accountable to complete all session components in the same way with each participant. A summary of the health coaching components, health coach record sheets, and examples of the activPAL graphical feedback targeted to the specific intervention group (SUN^{STS}, SUN^{SL}) are in Appendix B.

Procedures

At each of the four sites, screening, informed consent, and baseline measures, except activPAL monitoring, were assessed in a common room of the living facility. Participants completed an interview-assisted screening and then informed consent with a research assistant, trained in measurement and evaluation for the study measures and working with older adults. Measurement research assistants were different than health coaches. The informed consent followed a "repeat back" procedure with the research assistant to assure the participant understood what was being asked of them. Next, participants (N = 71) who consented to the study, completed the physical and self-report measures and then received a thigh-worn activPAL inclinometer to wear for 7 full days prior to the study. A review on the activPAL by Edwardson et al., (2017) summarized protocols using the activPAL for over 50 studies. Studies ranged from administering the device for 1 day to 14 days. Seven days for the initial baseline wear was chosen based on recommendations from the review by Edwardson et al., (2017). Most of the reviewed studies (71%) administered the device for 7 days define valid wear time as at least 4 valid (> 10 hrs per day) days. Further, a previous study in an older adult residential care community administered the

device for 7 full days and reported 75.6% of their sample provided enough valid days to be used for the analyses (Reid et al., 2013). After the initial wear for the current study, in which all participants (100%, N = 71) provided valid wear (> 4 days), subsequent measures (6 and 12 week) were administered for 6 full days in order to keep the participant on their weekly health coach schedule. This strategy reduced participant burden and maximized retention in the study.

The activPAL was waterproofed with plastic wrap (polytubing cover and sealed with a heat gun) and attached with adhesive (Hypafix on skin and covered with Tegaderm^{TM}) to the mid-thigh. A research assistant instructed, demonstrated, and assisted, if needed, how and where to attach the device. The research assistant also gave participants an extra Tegaderm^{TM} cover in case participants chose to remove and reapply the device. The participant was also given a device paper log to record the sleep/wake time of he or she and any comments related to the activPAL (e.g., changed adhesive, changed legs, etc; example in Appendix C). All measures were completed again at 6 (mid-intervention), and 12 (post-intervention) weeks. An additional questionnaire at 12 weeks was included asking about participant satisfaction with the intervention components.

Measures

(Measures are found in Appendix C.)

Screening Measures

Pre-clinical Disability Questionnaire (PCD; Screening measure; Appendix C). This measure is an interview-assisted questionnaire that was modified from a 24-item questionnaire by Fried et al. (1996). Each item asks if the respondent has difficulty completing the task or if he/she modifies (i.e., compensates either through frequency or mode) the way he/she completes the task. To reduce participant burden we asked 12 questions (i.e., five primary movements, three basic ADLs, and four instrumental ADLs) as done in previous studies (Gibson et al., 2010; Wolinsky et al., 2005). These 12 items have evidence of predictive validity for onset of functional disability

one to two years later in middle-aged and older adults (Fried et al., 2000; Fried et al., 2001; Wolinsky et al., 2005). Wolinksy et al. (2005) found that those who reported a modification in one of the five primary movements were over twice as likely to not be able to complete that movement one year later compared with those reported no modification. Fried et al. (2000) found that those who reported a modification in stair climbing or walking ½ mile were four times more likely to not complete either movement 18 months later compared with those who reported no modification. This measure also has demonstrated excellent test-retest reliability in middle aged and older adults (> 50 years) (Miller et al., 2006). The test-retest reliability intraclass correlations coefficients (ICCs) over 5-18 days were > 0.78 for each item and > 0.80 for the sum of items in the three subscales (i.e., primary movements, ADLs, iADLs) and total sum of items as done in the current paper in Tables 3 and 4 (Miller et al., 2006). These questionnaire items have also been adapted and used as screening methods in other interventions for older adults and have been used with participants residing in private homes and retirement communities (De Labra et al., 2015; Gibson et al., 2010; Miller et al., 2006). During the baseline measurement, this questionnaire was part of the eligibility screening; participants will be eligible if they indicate they modify at least one of the five primary movements and one of the seven ADLs/iADLs.

Cognition (Screening measure). Cognition was assessed with the *teach back method* on the informed consent document. Throughout the reading and description of informed consent, the research assistant asked pre-determined questions such as, "how many weeks will you meet with your health coach?" or "what does it mean when the consent forms says this study is considered minimal risk?. This process assured participants knew what was being asked of them, gave participants time to ask clarifying questions, and allowed the research assistant to identify significant cognitive impairment.

Sedentary Behavior

Sedentary Behavior was objectively measured with the activPAL™ (activPAL™, Glasgow, Scotland). The activPAL is a small (1" x 2") device that was waterproofed with plastic wrap and taped with adhesive to the thigh. The device is the gold standard for SB measurement and has evidence of acceptability for being worn in studies with older adults (Reid et al., 2013; Rosenberg et al., 2015). Though distinct activPAL wear time protocols have not been published, Edwardson et al., (2017) reviewed over 50 studies with the activPAL and reported that nearly all studies adopted the standard PA device wear time protocol, using a minimum of four days (> 10hrs/day with at least one weekend day) as a valid wear time criterion (Matthews et al., 2012). This protocol was also used in recent older adult SB interventions and variables were summarized as daily averages (e.g., hours per day of sitting) for all participants that provided at least four valid days (Fitzsimmons et al., 2013; Rosenberg et al., 2015). A ***device sleep/wake log*** was given to participants to record their sleep/wake times to allow the researcher to remove sleeping hours from the SB analyses.

Physical Function and Mobility (Appendix C)

Physical Function was assessed with the *Short Physical Performance Battery* (SPPB). The SPPB is a widely-used measure of physical function in older adults, including lower functioning oldr adult samples, consisting of three exercises (balance test, 4-meter gait test, and 5 chair-rises) that are scored on a scale of 0-4 and summed for a total score of 0-12; high scores indicate a higher level of function (Guralnik et al., 1994). Evidence exists for reliability and validity of the SPPB as a measure of physical function in older adults (Freire et al., 2012; Gomez et al., 2013; Gurlanik et al., 2000; Mangione et al., 2010; Penninx et al., 2000; Vasunilashorn et al., 2009). Test-retest reliability has been reported in several studies, including samples of older

adults of varying ethnicities, with ICCs all above 0.81 with tests 4-7 days apart (Freire et al., 2012; Gomez et al., 2013; Mangione et al., 2010). The SPPB also has evidence of predictive validity for future disability in older adults (Gurlanik et al., 2000; Penninx et al., 2000; Vasunilashorn et al, 2009). A score of ≤ 9 (moderate function) and ≤ 7 (low function) are associated with a 4- and 32-fold increased risk for disability within three years, respectively (Vasunilashorn et al., 2009). Thus, we have selected a score of ≤ 8 as an inclusion criterion to target participants who will benefit most from the intervention and who are at the highest risk for future disability in ADLs.

Mobility was assessed with the *8-ft up-and-go (8ft UG).* This test is a comprehensive measure of agility, mobility, gait efficiency, and balance (Rilki & Jones, 1999). The 8ft UG has good reliability and validity evidence in older adults, has been shown to be a predictor of falls, and has good discriminatory validity between fallers and non-fallers (Rose, Jones, & Luchese, 2002; Shumway-Cook et al., 2000). The 8ft UG has been shown to be significantly related to the Berg Balance Scale (r = -0.81), gait speed (r = 0.61), and the Barthel index of ADLs (r = 0.78) (Rikli & Jones, 1999). Test-retest reliability was also high (ICC = 0.95) when given 2-5 days apart with community-dwelling older adults of varying functioning levels (Rikli & Jones, 1999). Rose et al., (2002) reported fallers took 8.5 seconds or longer to complete the test. Johansen et al., (2016) also reported high interrater reliability (ICC = 0.96) in their sample of hospitalized stroke patients, who had a comparable mean 8ft UG time as that found in the current study.

Depressive Symptoms (Appendix C)

Depressive symptoms were assessed with the *Center for Epidemiologic Studies Depression Scale* (*CES-D) Short Form*, a 10-item survey that has evidence of validity and reliability in older adults (Andresen et al., 1994; Karim et al., 2015). Andresen et al. (1994) reported good predictive ability against the full 20-item CES-D (kappa = 0.97), as well as evidence of construct validity

with a strong negative correlation with positive affect (r = -0.63) in older adults. Karim et al. (2015) reported high internal consistency (Cronbach's alpha = 0.84) and evidence of construct validity, showing negative associations between the CES-D and life satisfaction, self-esteem, optimism, autonomy, social trust and a positive association with anxiety in over 13,000 older adults over 60 years old. Items ask how often someone experiences depressive symptoms (0-3) and a total score is a sum of all items (0-30) with higher scores indicating higher levels of depressive symptoms; a score of ≥ 10 is considered "depressed".

Activities of Daily Living (Appendix C)

Activities of Daily Living (ADLs) were assessed and used as both a screening measure and a potential covariate in examining dependent variables of interest. Items from the PCD questionnaire asking about difficulty or a modification in five primary movements, three basic ADLs, and four instrumental ADLs (iADLs). Each group (i.e., primary movements, ADLs, iADLs) of items were summed as well as a total sum of all 12 items, allocating one point to each item that was answered as "difficult" or "modified". In the current study, group items were used in screening following the guidelines of Fried et al. (1991) to determine pre-clinical disability status, and total sum scores were used as potential covariates in analyses, as appropriate. Miller et al., (2006) reported high test-retest reliability ICCs for each item (>0.78) and for the sum of the subscales (>0.80). These items were used to describe the level of functioning in the current study sample and were examined as a potential covariate in analyses.

activPAL Compliance & Satisfaction (Appendix C)

activPAL Device Acceptability and Compliance was assessed through documentation of percentage of participants providing valid wear days (> 10 hrs/day of waking hours) at the baseline measure from no valid days to 7 days and percentage of returned and completed (> 75% complete)

sleep/wake logs. For those who did not fully complete the sleep/wake log we also documented partially complete (25 – 75%) and incomplete (< 25%) logs. We also documented the number of times individuals indicated they changed the adhesive on the device. This protocol for valid wear time and days and use of a participant sleep/wake log is currently the most widely used protocol for the activPAL (Edwardson et al., 2017).

Edwardson et al. (2017) reported baseline measure activPAL compliance from five large (N = 187 to N = 1,308) randomized controlled trials (RCTs) in adults at risk for type II Diabetes Mellites and in the general adult population aged 18-75 years. These studies all administered a continuous wear protocol for 7 days and ranged from 63.6% to 99.6% of their sample providing ≥ 4 valid days. In the longest (8 weeks) previous older adult SB intervention using the activPAL, Rosenberg et al. (2015) reported 92% of their sample provided valid activPAL data. Over half of the studies in the review by Edwardson et al., (2017) report administering a sleep/wake log to help omit sleep time, however there is little data on the number of logs that were completed.

activPAL Device Satisfaction (Appendix C) was measured with a brief survey rating acceptability of wearing the device with various questions after the baseline measurement. For example, how bothered participants were by the device on a scale from 1 (not bothersome at all) to 5 (very bothersome). All participants were given the option to re-wear the device during their first week of the health coach sessions to examine their immediate graphical feedback at their week two health coach session. We documented the percentage of those who re-wore the device. This survey was created by the PI based on available data about the participant experience with the activPAL and to contribute to a greater understanding of the satisfaction with the activPAL in this population. Items were formed based on considerations (e.g., bothersome, skin irritation, adhesive) that were described in Edwardson et al., (2017).

SUN Intervention Satisfaction (Appendix C)

Satisfaction with Intervention Components was assessed at 12 weeks. We administered a satisfaction survey with 8-items after week 12 asking about satisfaction with the intervention components. Participants ranked intervention components on a scale of 1 (not helpful) to 5 (very helpful). Intervention components included questions about in-person health coach sessions (e.g., length, conversation/interaction, goal setting, content/graphical feedback chart) and phone calls (number, length, content) and were the same for both SUN groups. This survey was adapted from Rosenberg et al., (2015) who also administered a satisfaction survey to their participants after 8 weeks asking about similar intervention components (e.g., graphical feedback, intervention materials, health coach sessions).

activPAL Data Processing and Cleaning

activPAL™ software (PALTechnologies, v7.2.38, Glasgow, Scotland) was used to initialize the devices with minimum time to detect change in posture at 1-second. This time period represents the minimum sitting/upright period (MSUP) that the device will register to detect a change in sit to stand positioning after 1-second. This value was chosen to the reflect the intervention, as health coaches directed participants that they needed to stand up for at least 1-second to capture a STS transition. Most previous SB interventions did not report the method of data processing, however, the software default values are set at 10-seconds (Edwardson et al., 2017). If we had used the 10-second default value, this decision would likely miss meaningful STS transitions of participants. Kerr et al. (2015) reported re-processing files with 1-second values and found their intervention group met intervention goals (i.e., adding 30 STS transitions per day), while they did not when processed at the 10-second default MSUP. After wearing, all activPAL data were downloaded and saved in multiple file formats (PAL, DATX, CSV). First the PAL file

was used to compare with the provided sleep logs from the participants. All sleep logs were individually compared with activPAL data (PAL file) by a research assistant to confirm accuracy of sleep/wake times. When there was a discrepancy found, the PAL file was used as the trusted source for entering sleep/wake times for data. For example, when the participant indicated he or she woke up at 8:00AM, yet the file showed standing or stepping at 7:00AM, we used 7:00AM as their awake time. When a sleep log was not provided, two research assistants, trained in activPAL data processing, separately used the PAL file to estimate sleep/wake times, based on movement and then cross checked each of their created logs. Together, the research assistants came to a consensus. The "Events File" (comma separated values file (csv)) was imported and processed in RStudio (R version 3.5.1). The R package activpalProcessing (Lyden, 2016) was used to generate a "second-by-second" file and then used to summarize the number of sit-to-stand transitions (STS), number of steps, and time spent stepping, sitting, and standing for each day worn for each participant. Invalid days (<10 waking hours) were removed. Then, participants with less than four valid days were excluded. After data processing and before analysis, each observation (participant, day, and visit for each variable) was checked by two separate research assistants and compared with the PAL file again. Noticeable discrepancies were found when there was a manual error entry in sleep/wake logs and then data were corrected and reprocessed. Approximately 50 discrepancies of over 1,000 observations were corrected. After all data cleaning and checking, each activPAL variable was averaged across the number of valid days provided by the participant and used for analyses.

Analyses

Data were processed and analyzed using SPSS (IBM Statistics Version 25.0) and RStudio (R version 3.5.1). Descriptive statistics, frequency counts, normality, outlier identification (>2.58

SD's from mean), and group comparisons for all variables were calculated (Weiner, Schinka, & Velicer, 2003). Chi-Square tests were used for categorical data and independent t-tests were used for continuous variables to compare differences between groups for baseline variables. An alpha level of 0.05 was used for statistical significance.

Changes in outcomes

Linear mixed models were used to test the efficacy of the intervention group (SUN^{STS}, SUN^{SL}) to change outcome variables in **Table 6** over time (0, 6, 12 weeks). Linear Mixed Modeling (LMM) using SPSS (version 24.0) MIXED procedure was used to examine intervention effects and to account for potential clustering of data based on intervention site. A 3-level model was specified with repeated measures (baseline, 6 weeks, 12 weeks) nested within participants, nested within site. Intraclass correlation coefficients (ICCs) were examined for clustering effects in unconditional models, with intervention group (SUN^{STS} or SUN^{SL}) and the interaction of group and time included in full model testing to examine dependency of any changes over time on group for each dependent variable of interest (**Table 6**). We examined correlations of potential covariates such as age, health coach session attendance, gender, and activPAL device wear time. If variables were at least moderately correlated (Pearson's $r > 0.4$) with outcome variables they were included in models as covariates and remained if indicated in model refinement. Effect sizes (Cohen's *d*)

were calculated for SUN^{STS} and SUN^{SL} differences in outcome variables at each time point using pooled standard deviations adjusted for group sizes.

Table 6. *Outcome Variable and Measure Used for Linear Mixed Models*

Outcome:	**Measure**
Sedentary Behavior:	activPAL:
Sit-to-stand transitions	Average #/d
Sitting Time	Average time/d
Sitting %	% of sitting of waking time
Standing Time	Average time/d
Stepping Time	Average time/d
Steps	Steps/d (#)
Physical Function	SPPB (0-12)
Balance	Balance Score (0-4)
Gait Speed Score	Gait Speed Score (0-4)
Gait Speed II	Gait Speed time (m/s)
Lower body strength	Chair Rise (0-4)
Mobility	8-ft up-and-go (seconds)
Depressive Symptoms	CES-D (0-30)

Note. CES-D = Center for Epidemiologic Studies Depression Scale (CES-D) Short Form

activPAL Acceptability, Compliance, and Satisfaction

Descriptive statistics from the number of valid wear days and completed sleep/wake logs were summarized for activPAL compliance and acceptability. Descriptive statistics from the survey were reported for activPAL satisfaction.

Intervention Compliance and Satisfaction

Attendance as well as descriptive statistics from the intervention satisfaction survey were reported for satisfaction with the components of the intervention. We reported two groups: Completers and high attenders. Completers were considered participants who completed all three time-points. We also considered those who had high (>67% attendance as high attenders) attendance of the health coach sessions, compare to those with low (<66.9% attendance as low attenders) attendance.

Sample Size

Because this intervention is the first study to examine changes in SB in this population and setting, the focus was on feasibility to recruit and retain participants of moderate-to-low physical function, change SB, and acceptability and responsiveness of the participants to the intervention. A previous pilot intervention in CCRCs used four sites and ended with a total of 64 of 87 participants (74% retention) after a 12-week walking intervention with older adults of higher physical function (Rosenberg et al., 2009). Another study conducted in assisted living settings with seven days of activPAL measurement had 25% missing data from their device measurement (Ried et al., 2013). Other SB pilot interventions in older adults have ranged from 2 weeks to 12 weeks with sample sizes from 24 to 38. One study incorporated two intervention groups such as the current study and had 18 participants per group for a total of 36 participants over two weeks (Kerr et al., 2016). Rosenberg et al., (2015) had a significant reduction in SB with 27 minutes over 8 weeks with 25 participants in a single group (effect size d = 0.25). Thus, we aimed to recruit 22 participants from each site to account for a 30% attrition rate to achieve a total of 15 participants per site and 60 total participants. With three time-points, our method of statistical analysis allowed us to use all available data to have more power to detect changes in outcome measures than previous interventions with only two time points and analyses that only used complete cases.

The Methods chapter, in part, are currently being prepared for submission for publication. Thralls, Katie J.; Levy, Susan S. The dissertation author was primary author of this material.

Results

Sites and Participants

A total of 71 participants (n = 38 SUN^{STS}; n = 33 SUN^{SL}) from four sites completed baseline measures. Sixty (n = 32 SUN^{STS}; n = 28 SUN^{SL}) and fifty-eight (n = 30 SUN^{STS}; n = 28 SUN^{SL}) participants completed 6- and 12- week measurements, respectively (***Figure 1***). Fifty-eight (80%) participants had high (> 67%) attendance to the health coach sessions. There were no differences between dropouts and completers (i.e., completed all measurements) or in the attendance (high vs. low attendance) group in demographics, activities of daily living, or baseline outcome variables (i.e., sedentary behavior, physical function, or depressive; *ps* > 0.05; **Table 7**). ***Figure 1*** summarizes a flow chart of participants throughout the study and reasons for dropout. Demographics and level of modification or difficulty with ADLs are broken down by group at baseline in **Tables 2-4**, and further reported broken down by each site in Appendix A (**Tables A2-A6**).

Table 7. *Differences between Completers and Attendance Groups*

	Completers (n=58)	Dropouts (n=13)	p-value	High Attendance (>67%) (n=57)	Low Attendance (n=14)	p-value
Group			0.521			0.766
STS	52%(n=30)	61% (n=8)		53% (n=30)	57% (n=8)	
SL	48% (n=28)	39% (n=5)		47% (n=27)	43% (n=6)	
Age (years)	87 (6.4)	87 (5.1)	0.967	86.7 (6.5)	86.5 (7.1)	0.87
Gender (%Female)	80% (n=46)		0.273	77% (n=44)	100% (n=14)	0.15
Ethnicity (%Caucasian)	90% (n=52)	92% (n=12)	0.8	88% (n=50)	100% (n=14)	0.239
Education (%Completed College)	57% (n=33)	38% (n=5)	0.289	56% (n=34)	43% (n=6)	0.455
Marital Status (%Widowed)	59% (n=34)	54% (n=7)	0.087	60% (n=34)	50% (n=7)	0.499
SPPB Score	5.0 (1.9)	5.2 (2.1)	0.818	5.0 (1.9)	5.3 (2.1)	0.599
CESD Score	5.8 (4.7)	7.6 (3.8)	0.741	5.5 (4.4)	8.5 (4.4)	0.688
PCD_Total_Score	5.5 (2.0)	4.8 (2.2)	0.243	4.8 (2.1)	5.5 (2.1)	0.463
AP Variables:						
STS (#/d)	54 (17)	56 (16)	0.663	54 (17)	57 (15)	0.424
Sitting (h/d)	10.9 (1.9)	10.9 (1.5)	0.946	10.9 (1.9)	10.9 (1.8)	0.995
Standing (h/d)	3.6 (2.0)	2.8 (1.5)	0.251	3.6 (2.0)	3.0 (1.5)	0.484
Stepping (h/d)	1.0 (0.5)	0.8 (0.6)	0.323	1.0 (.5)	0.9 (0.6)	0.531

Note. STS = sit-to-stand transitions; SL = Sit Less; SPPB = Short Physical Performance Battery; CES-D =Center for Epidemiologic Studies Depression Scale; PCD = Pre-Clinical Disability; AP = activPAL; Completers = completed all 3 measurement points; High attendance = >67% attendance; Chi-squares used for categorical data and independent t-tests for continuous data

activPAL Data

Descriptives

After activPAL data were processed using activPAL^{TM} software (PALTechnologies, v7.2.38, Glasgow, Scotland), variables were aggregated by mean value per day and are summarized in **Table 8**, broken down by group (SUN^{STS}, SUN^{SL}) and at all three time points. Two participants' activPAL data were initially removed from all time points due to questionable validity. One participant had Parkinson's disease revealing seemingly inflated STS transitions and

standing time; the other revealed an unreasonable value for "standing" of > 10 hours per day, leaving 69 participants with valid baseline activPAL data for analyses. There were no significant differences (*ps* > 0.05) between intervention groups (SUN^{STS}, SUN^{SL}) for activPAL variables except for number of steps with the SUN^{STS} group having significantly more steps than the SUN^{SL} group ($p < 0.03$).

Table 8. *Descriptive statistics for activPAL Variables by Group and Time (continued next page)*

	Baseline *			Mid intervention (6 weeks)*			Post intervention (12 weeks)*		
AP Variable:	**STS (n=36)**	**SL (n=33)**	**Total (N=69)**	**STS (n=32)**	**SL (n=26)**	**Total (N=58)**	**STS (n=30)**	**SL (n=26)**	**Total (N=56)**
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
STS (#/d)	54.9(17.4)	54.5(16.7)	55(17)	60.3(18)	57.2(23.3)	58.9(20.4)	57(19)	55(19.7)	56.2(19.2)
95% CI	49 to 60	48 to 61	51 to 59	54 to 67	48 to 67	54 to 64	57 to 64	47 to 63	51 to 61
STS (#/d)+	54.9(17.4)	53.9(17)	54(17)	60.3(18)[A]	54.7(20)	58(19)	57(19)[B]	53.6(18)	55(18)
95% CI	49 to 60	48 to 60	50 to 58	54 to 67	46 to 63	53 to 63	57 to 64	46 to 61	50 to 60
Sitting (hr/d)	11.1(1.6)	11(1.9)	11.1(1.7)	10.3(1.5)	9.8(1.8)	10.1(1.6)	10.4 (2.3)	9.8(1.7)	10.1(2.1)
95% CI	10.6 to 11.6	10.3 to 11.7	10.7 to 11.5	9.8 to 10.9	9.0 to 10.5	10.0 to 10.2	9.5 to 11.3	9.1 to 10.4	9.5 to 10.6
Sitting (hr/d)^	11.1(1.6)	11.2(1.7)	11.4(1.6)	10.3(1.5)[A]	9.9(1.6)[A]	10.1(1.5)[A]	10.4 (2.3)[A]	9.9(1.6)[A]	10.1(2.0)[A]
95% CI	10.6 to 11.6	10.5 to 11.6	11.1 to 11.7	9.8 to 10.9	9.1 to 10.4	9.7 to 10.5	9.5 to 11.3	9.1 to 10.4	9.7 to 10.5
Sitting (%/d)	73.4(11.4)	74.2(11.4)	73.8(11.3)	69.8(11.1)	70.3(11.7)	70(11.0)	71 (12.0)	69.4(11.8)	70(13.0)
95% CI	70 to 77	70 to 78	71 to 76	66 to 74	66 to 75	67 to 73	65 to 76	65 to 74	66 to 73
Sitting (%/d)^^	73.4(11.4)	75.1(10.4)	74.1(10.9)	69.8(11.1)[A]	71.4(10.5)[A]	70.5(10.7)[A]	71 (12)[A]	70.5(10.7)[A]	70.5(12.7)[A]
95% CI	70 to 77	71 to 79	72 to 74	66 to 74	66 to 75	68 to 73	65 to 76	65 to 74	68 to 73
Standing (hr/d)	3.3(1.7)	3.3(1.5)	3.3(1.6)	3.7(1.6)	3.6(1.6)	3.6(1.6)	3.6(1.9)	3.7(1.7)	3.7(1.8)
95% CI	2.7 to 3.8	2.7 to 3.8	2.9 to 3.7	3.1 to 4.3	3.2 to 4.1	3.2 to 4.1	2.9 to 4.3	3.1 to 4.4	3.2 to 4.2
Standing (hr/d)++	3.2(1.5)	3.3(1.5)	3.2(1.5)	3.5(1.4)[A]	3.6(1.6)[A]	3.6(1.5)[A]	3.4(1.6)[A]	3.7(1.7)[A]	3.6(1.6)[A]
95% CI	2.7 to 3.8	2.6 to 3.6	2.9 to 3.6	3.1 to 4.3	3.0 to 4.2	3.2 to 3.95	2.9 to 4.3	3.1 to 4.4	3.1 to 4.0

*Note. *Removed 2 participants that had questionable data; ^ removed 1 outlier; **removed 2 outliers; +removed 1 outlier; A = significantly ($p<0.05$) different from baseline; B = significantly ($p<0.05$) different from 6 weeks; Variables without outliers were used for data analysis; M = Mean; SD = Standard Deviations; AP = activPAL; CI = Confidence Intervals*

Table 8. *Descriptive statistics for activPAL Variables by Group and Time (continued from previous page)*

	Baseline *			Mid intervention (6 weeks)*			Post intervention (12 weeks)*		
AP Variable:	**STS (n=36)**	**SL (n=33)**	**Total (N=69)**	**STS (n=32)**	**SL (n=26)**	**Total (N=58)**	**STS (n=30)**	**SL (n=26)**	**Total (N=56)**
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
Stepping (hr/d)	1.14(0.596	0.85(0.4)	1.01(0.5)	1.2(0.6)	0.94(0.5)	1.1(0.5)	1.3(0.6)	0.9(0.4)	1.05(0.5)
95% CI	0.9 to 1.3	0.7 to 1.0	0.9 to 1.1	1.0 to 1.4	0.75 to 1.1	0.93 to 1.2	0.9 to 1.4	0.8 to 1.1	0.9 to 1.2
Stepping (hr/d)**	1.05(0.5)	0.85(0.4)	0.96(0.4)	1.1(0.5)	0.94(0.5)	1.1(.5)	1.1(.5)	0.9(0.4)	1.0(0.5)
95% CI	0.9 to 1.2	0.7 to 1.0	0.8 to 1.1	1.0 to 1.2	0.75 to 1.1	0.9 to 1.2	0.9 to 1.3	0.8 to 1.1	0.9 to 1.1
Steps (#/d)	5249(2994)	3693(2096)	4550(2724)	5381(2943)	4132(2498)	4821(2800)	5243(3112)	4118(2310)	4720(2802)
95% CI	4265 to 6233	2925 to 4462	3896 to 5204	4320 to 6442	3124 to 5141	4085 to 5558	4081 to 6405	4118 to 3185	3970 to 5471
Steps (#/d)**	4812(2393)	3693(2096)	4295(2313)	5111(2556)	4132(2498)	4665(2555)	4949(2712)	4118(2310)	4556(2541)
95% CI	4002 to 5622	2924 to 4462	3730 to 4859	4173 to 6049	3124 to 5141	3987 to 5343	3918 to 5981	3185 to 5051	3869 to 5243

Note. *Removed 2 participants that had questionable data; ^ removed 1 outlier; **removed 2 outliers; +removed 1 outlier; A = significantly ($p<0.05$) different from baseline; B = significantly ($p<0.05$) different from 6 weeks; Variables without outliers were used for data analysis; M = Mean; SD = Standard Deviations; AP = activPAL; CI = Confidence Intervals

activPAL Compliance

All participants (N = 71) provided valid activPAL data with at least four valid days (>10 hours per day) for baseline measurements with the total sample providing a mean of 6.83 (SD = 0.51) days at baseline. Sixty-three (88.7%) provided seven complete days, four (5.6%) provided six days, and four (5.6%) provided five days of data at baseline measurement (Appendix A, **Table A7**). All available valid days were used to aggregate all activPAL variables (i.e., STS transitions, SB time, standing time, stepping time, and steps) as an average per day for each participant.

To examine compliance for completing the sleep/wake log, which was used to exclude sleep from device-registered sedentary behavior, we documented how many logs were completed (>75% completed log), partially completed (25%-75% completed log) or not completed (<25% completed log). At baseline, 53 (75%) participants fully completed their sleep logs, three (4%) partially completed, and 15 (21%) did not complete the sleep log (Appendix A, **Table A8**).

activPAL Satisfaction

After their baseline week of wearing the device, the interview-assisted activPAL satisfaction survey indicated that 92.8% (n = 64) of participants found that the device was not bothersome at all. Most participants (88.4%; n = 61) did not change the adhesive or need outside help (91.3%; n = 63) with anything related to the device. Nearly 80% (n = 55) indicated they were willing to re-wear the device again, as they would need to for mid-intervention (6-week) and post-intervention (12-week) measures. All participants were given the option to re-wear after the first health coaching session if they wanted to have activPAL graphical feedback at their second health coach session. Although 55 (79.7%) indicated they would re-wear the device, 42% (n = 30) did wear the device for the following week while the others indicated they would rather wait until week six. There were no differences in any activPAL variables at baseline, mid-intervention, or

post-intervention between participants that did (42%; n = 30) and did not wear (58%; n = 41) the device during that first week of the intervention (*ps* > 0.05). Four (5.6%) participants reported a minor skin irritation. All four of these participants continued the study and re-wore the device at six and 12-week measures. They did not experience an irritation at the subsequent measures.

Changes in activPAL variables over time

Covariates for outcomes.

We examined Pearson's Product Moment correlations of age, attendance at health coach sessions, length of residence at the facility, activities of daily living (baseline sum of PCD questions), physical function (baseline SPPB score), and mobility (8-ft up-and-go time) with activPAL variables as potential covariates. All variables were weakly correlated (r = 0.02 to 0.3), except between step count (r = -0.4; $p < 0.05$) and stepping time (r = -0.4; $p < 0.05$) with baseline PCD score (modifications/difficulties with activities of daily living shown in **Table 3**). Thus, we included the baseline PCD score variable as a covariate in our analyses for stepping time and step count.

Changes in activPAL variables: STS transitions per day

We fit a three-level linear mixed model (LMM) with random effects for participants and sites accounting for any clustering effects to examine the efficacy of SUN on STS transitions per day with fixed main effects for time (0, 6, 12 weeks), group (SUN^{STS}, SUN^{SL}), and a group X time interaction. One outlier (>2.58 SDs from mean) was removed due to invalid STS/d data caused by frequent swimming which noticeably inflated false positive STS/d counts (Weiner et al., 2003). Site ICC was low (ICC = < 0.001), indicating little variance explained by site, and the model failed to converge during full model testing. Therefore, this factor was removed during model refinement. Thus, we fit a restricted estimate of maximum likelihood (REML) model. There was

a significant main effect for time (F (2, 55) = 6.6, $p < 0.004$), no main effect for group (F (1, 66) = 0.12, $p < 0.77$), and a trend towards a group X time interaction (F (2, 55) = 2.5, $p < 0.094$). The SUN^{STS} group had significant increases in STS/d from baseline to 6 weeks ($p < 0.001$) with no difference in STS/d over time in the SUN^{SL} group ($p > 0.9$) as visualized in ***Figure 3***.

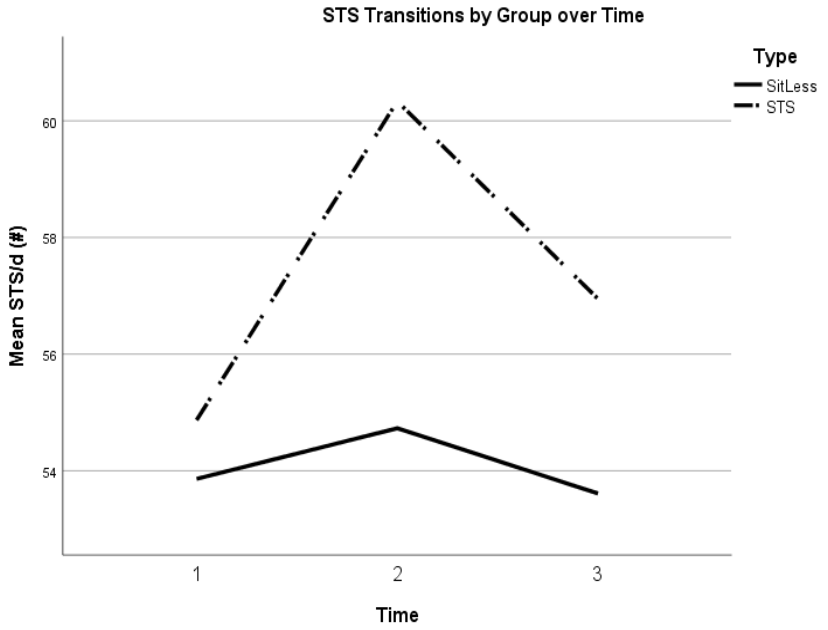


Figure 3. *STS transitions by group over time all points.*

Changes in AP variables: Sitting time of waking hours & Sitting as % of waking hours.

The same modeling process as STS transitions was used to fit a three-level LMM to examine the efficacy of SUN on average sitting time per day of waking hours and percent of sitting of waking hours with fixed effects for time (0, 6, 12 weeks), group (SUN^{STS}, SUN^{SL}), and a group X time interaction. One outlier (>2.58 SDs from mean) was removed due to minimal sitting time (Weiner et al., 2003). Similar to our previous LMM, we first included random effects for participants and sites. However, due to low ICCs for sites (ICC = <0.001), the model failed to converge. We removed the random effect for site, and fit an REML model. There was no

significant group X time interaction (F (2, 114) = 0.497, $p < 0.62$). Thus, we removed the non-significant interaction. The final model for total sitting time showed a significant main effect for time (F (2, 116) = 17.9, $p < 0.001$) and no main effect for group (F (1, 67) = 0.146, $p < 0.71$). There was a significant decrease in minutes per day of sitting from baseline to 6 weeks ($p < 0.001$) and no significant differences between 6 weeks and 12 weeks ($p > 0.99$) for both groups (SUN^{STS}, SUN^{SL}; ***Figure 4***).

We also fit an LMM for sitting as a percent of waking hours to ensure decrease in waking hours of sitting was not due to less awake time. For sitting time, summarized as a percent of waking hours, there was a significant main effect for time (F (2, 112) = 10.0, $p < 0.001$) and no main effect for group (F (1, 66) =0.213, $p < 0.66$). ***Figure 5*** shows similar findings with significant decreases from baseline to 6 weeks ($p < 0.001$) and no significant differences between 6 weeks and 12 weeks ($p < 0.97$) for both groups, supporting that the decrease in sitting hours was not simply due to more sleeping time.

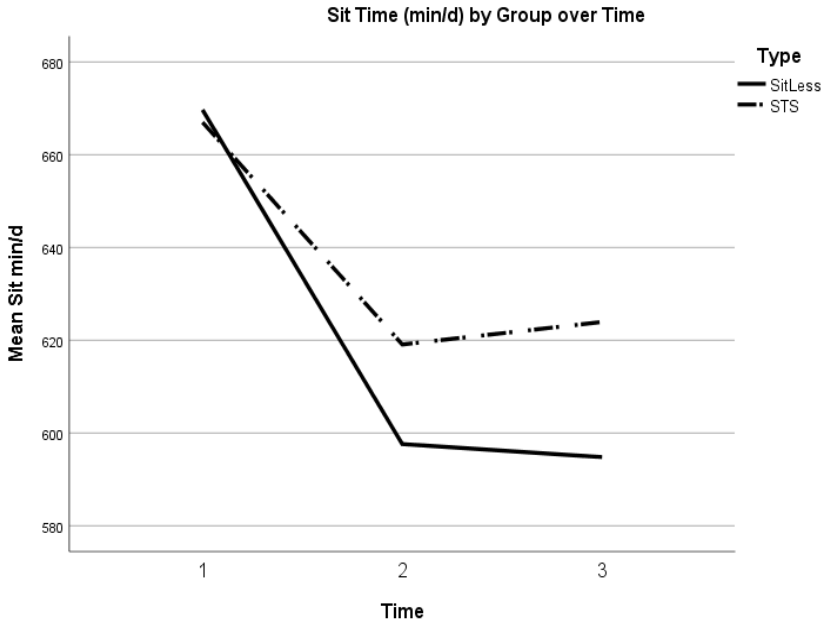


Figure 4. *Sitting time by group over time points.*

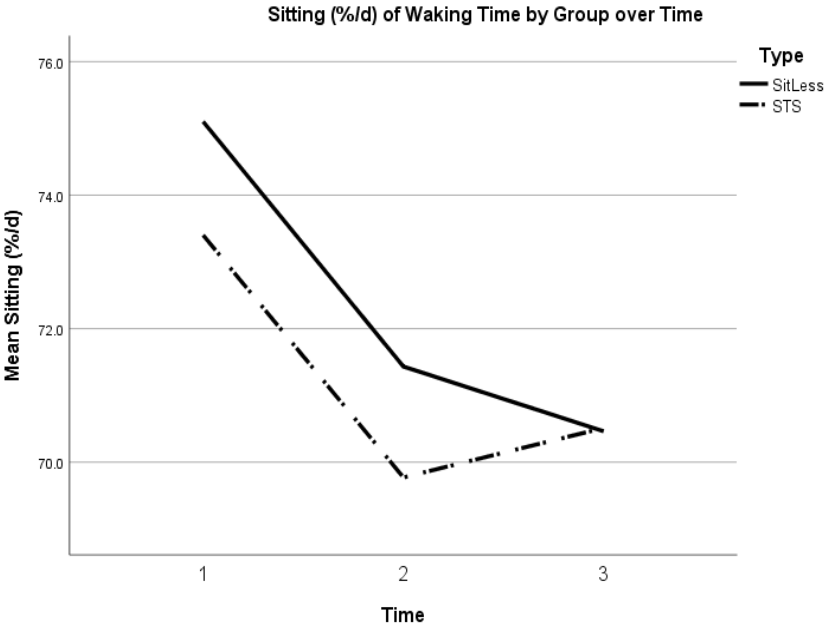


Figure 5. *Sitting percent by group over time points.*

Changes in activPAL Variable: Standing time

An LMM was fit to examine the efficacy of SUN on average standing time per day with fixed effects for time (0, 6, 12 weeks), group (SUN^{STS}, SUN^{SL}), and a group X time interaction. The same outlier as the models with sitting time and sitting percent was also removed from this model for excessive standing time (>2.58 SDs from mean) (Weiner et al., 2003). Similar to our previous models, we first included random effects for participants and sites. However, due to low intra-class correlations (ICCs) for sites (ICC = < 0.001), the model failed to converge. We removed the random effect for site, and fit an REML model. The non-significant interaction was removed ($F (2, 110) = 0.35$, $p < 0.71$) during model refinement, after which there was a significant main effect for time ($F (2, 112) = 4.1$, $p < 0.02$) and no significant main effect for group ($F (1, 66) = 0.068$, $p < 0.80$). Similar to sitting, there were significant increases from baseline to six weeks ($p < 0.03$) and no significant changes from six weeks to 12 weeks for both groups (***Figure 6***).

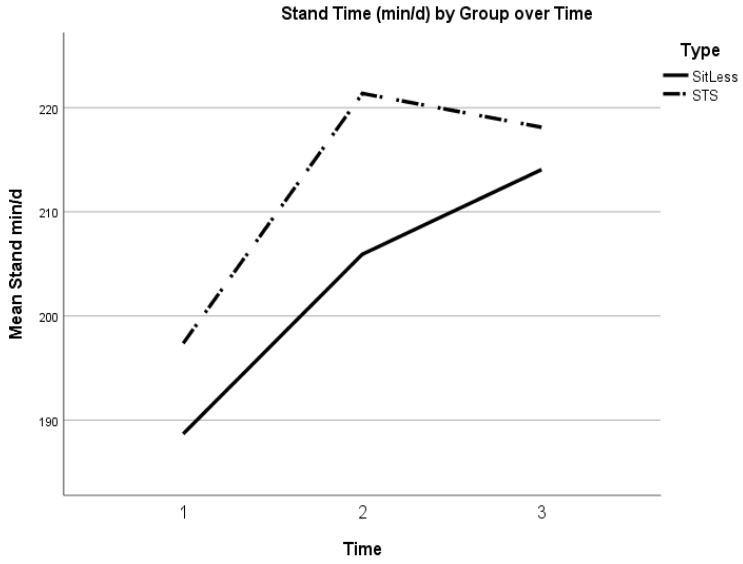


Figure 6. *Standing time by group over time points.*

Changes in AP Variables: Stepping time and number of steps

We then fit an LMM to examine the efficacy of SUN on average stepping time per day and number of steps with fixed effects for time (0, 6, 12 weeks), group (SUN^{STS}, SUN^{SL}), and a group X time interaction. Two outliers (>2.58 SD's above mean) were removed (Weiner et al., 2003). Further, due to a moderate correlation (r = 0.40) between the number of ADLs that participants had difficulty to complete (i.e., baseline sum of PCD questionnaire items, **Table 4**) and stepping time and step count, we included this variable as a covariate. As in previous models, random effects for participants and site were included. However, due to low intra-class correlations (ICCs) for sites (ICC < 0.001), the model failed to converge and the random effect for site was removed. During further model refinement, the non-significant interaction was removed ($F(2, 110) = 1.7$, $p < 0.20$); there were no significant main effects for time ($F(2, 112) = 1.7$, $p < 0.20$) or group ($F(1, 57) = 2.2$, $p < 0.16$). Similarly, for number of steps, the non-significant interaction was removed ($F(2,110) = 1.6$, $p < 0.22$); there were also no significant main effects for time ($F(2,112) = 1.2$, $p < 0.32$) or group ($F(1, 57) = 2.3$, $p < 0.14$) (***Figures 7, 8***).

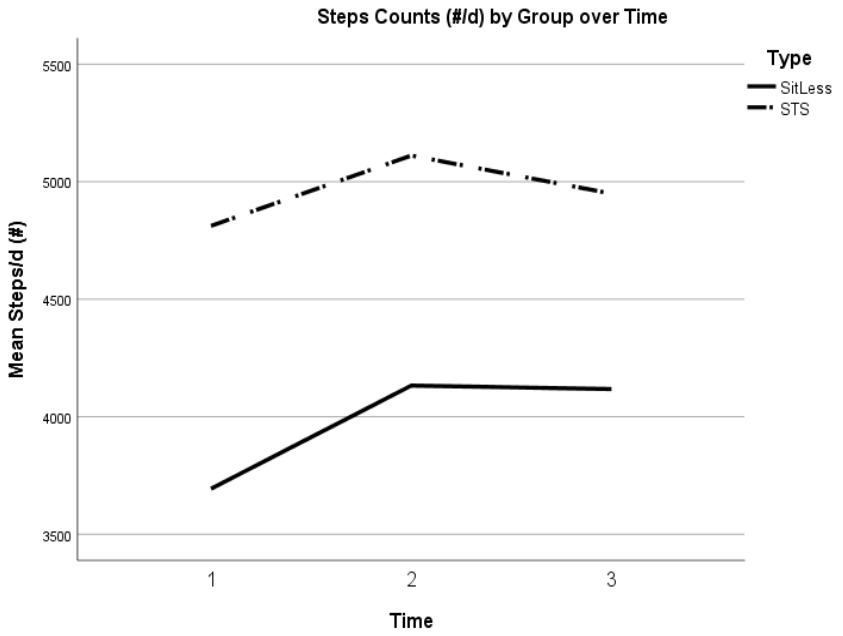


Figure 7. *Stepping time by group over time points.*

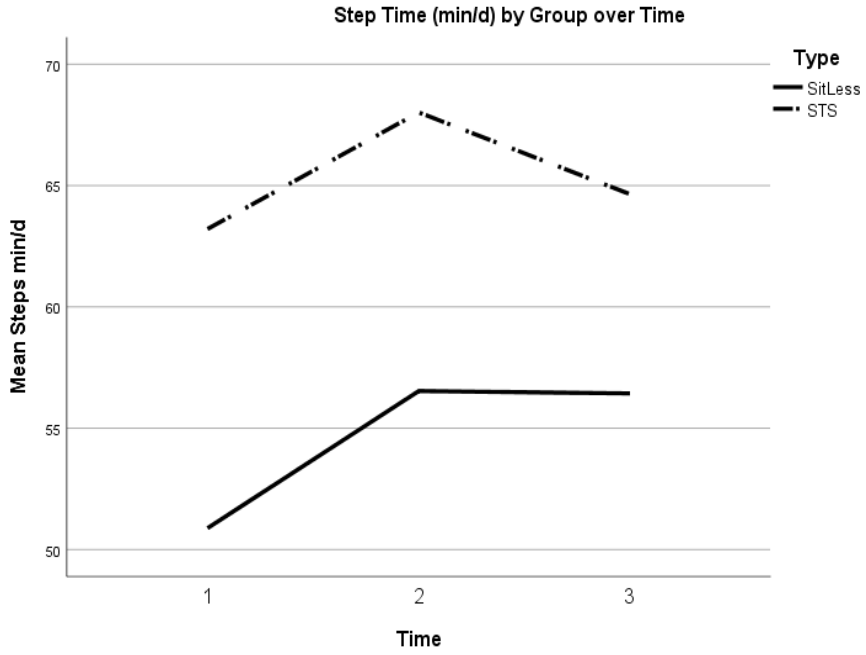


Figure 8. *Step count by group over time points.*

Physical Function: Short Physical Performance Battery (SPPB)

Descriptives with means (SDs) are presented in **Table 9** by group at each time point. Our sample had a mean SPPB score of 5.0 (SD = 1.9) out of 12.0 points. No signifncant differences were found between groups or sites at baseline for the SPPB or any sub-tests of the SPPB measure (*ps* > 0.05); **(Table 9).** We also calculated effect sizes (Cohen's *d*) for the SPPB total score and each sub test at each time point. These values are reported in **Table 10.**

Table 9. *Descriptives for Physical Function & Mobility by Group and Time Point*

	Baseline (N= 71)			Mid-intervention (N = 60; 6-weeks)			Post-intervention (N = 58; 12-weeks)		
Outcome Variable	**SUN^{STS} (N = 38)**	**SUN^{SL} (N=33)**	**Total (N=71)**	**SUN^{STS} (N = 32)**	**SUN^{SL} (N=28)**	**Total (N=60)**	**SUN^{STS} (N = 30)**	**SUN^{SL} (N=28)**	**Total (N=58)**
	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
SPPB Total (0-12)	5.2(1.7)	4.8(2.1)	5.0(1.9)	7.2(2.0)^{A}	6.1(3.0)^{A}	6.7(2.5)^{A}	7.5(2.3)^{A}	6.1(2.8)^{A}	6.8(2.6)^{A}
95% CI	4.7 to 5.8	4.2 to 5.7	4.6 to 5.6	6.5 to 7.9	5.0 to 7.4	6.1 to 7.4	6.6 to 8.4	5.0 to 7.2	6.3 to 7.7
Balance (0-4)	1.9(0.97)	1.8(0.83)	1.9(0.9)	3.0(.9)^{A}	2.6(1.1)^{A}	2.8(1.0)^{A}	3.1(0.91)^{A}	2.7(.9)^{A}	2.9(0.91)^{A}
95% CI	1.6 to 2.2	1.5 to 2.2	1.7 to 2.1	2.6 to 3.3	2.2 to 3.1	2.6 to 3.1	2.7 to 3.4	2.4 to 3.1	2.7 to 3.2
Gait Score (0-4)	2.2(0.78)	2.1(0.86)	2.2(.8)	2.8(.78)^{A}	2.4(1.2)^{A}	2.6(0.98)^{A}	2.9(0.92)^{A}	2.4(1.2)^{A}	2.7(1.1)^{A}
95% CI	2.0 to 2.5	1.9 to 2.5	2.0 to 2.4	2.5 to 3.1	2.0 to 2.9	2.4 to 2.9	2.6 to 3.2	2.0 to 2.9	2.4 to 3.0
Gait Speed* (sec)	7.0(1.6)	7.0(1.7)	7.0(1.6)	6.1(1.6)^{A}	6.6(2.2)^{A}	6.3(1.9)^{A}	5.7 (1.5)^{A}	6.8(2.7)^{A}	6.1(4.7)^{A}
95% CI	6.4 to 7.5	6.4 to 7.7	6.6 to 7.4	5.5 to 6.7	5.5 to 7.8	5.8 to 6.9	5.2 to 6.3	5.3 to 8.2	5.4 to 6.8
Chair Score (0-4)	1.1(1.0)	0.9(1.1)	1.0(1.1)	1.4(1.3)^{A}	1.1(1.3)^{A}	1.3(1.3)^{A}	1.6(1.3)^{A}	0.96(1.3)^{A}	1.3(1.3)^{A}
95% CI	0.7 to 1.4	0.5 to 1.4	0.8 to 1.3	1.0 to 1.9	0.5 to 1.6	0.9 to 1.6	1.1 to 2.0	0.5 to 1.5	0.98 to 1.7
Chair Completer^{+} %	63.2%(n=24)	48.5%(n=16)	56.3%(n=40)	71.8%(n=23)	42.9% (n=12)	58.3% (N=35)	76.7%(n=23)	42.9%(n=12)	60.3% (N=35)
8 ft up-and-go~ (sec)	14.6 (5.7)	15.9(7.1)	15.2(6.3)	13.2(5.3)	15.1(7.4)	14.0(6.2)	14.1(7.7)	16.7(11.4)	15.7(10.0)
95% CI	12.9 to 16.6	13.2 to 18.6	13.7 to 16.8	11.3 to 15.1	12.0 to 18.2	12.3 to 15.7	11.3 to 17.0	11.4 to 21.0	12.0 to 18.5

Note. * 4-meter usual walking pace; $^{+}$"Completer" = people that had > 0 seconds; ^{A} = significant difference from baseline. ~ removed 4 outliers (>2.58SDs);
CI = Confidence Intervals

Table 10. ***Effect sizes (Cohen's d) for SUN Group Differences at Each Time Point***

	Baseline	6 Weeks	12 Weeks
SPPB Total (0-12)	0.21	0.44	0.55
Balance (0-4)	0.11	0.4	0.44
Gait Score (0-4)	0.212	0.4	0.47
Gait Speed (sec)	<0.001	0.26	0.51
Chair Score (0-4)	0.19	0.23	0.49
8ft UG (sec)	0.2	0.3	0.27

Note. 8ft UG = 8-foot up-and-go

Changes in physical function

SPPB total score

We fit a three-level LMM to examine the efficacy of SUN on physical function, as measured by the SPPB test with a score of 0 to 12. We defined fixed main effects for time (0, 6, 12 weeks), group (SUN^{STS}, SUN^{SL}), and a group x time interaction. We included random effects for participants and sites. However, the ICCs for site (ICC =< 0.067) were low and the model failed to converge. Thus, we removed the random effect for site and fit a REML. There was no significant interaction ($F(2, 118) = 1.9$, $p < 0.16$) so we removed this parameter during model refinement. Our final model showed a significant main effect for time ($F(2, 120) = 41.2$, $p < 0.001$) and no main effect for group ($F(1, 69) = 2.9$, $p < 0.11$). There were significant increases from baseline to six weeks ($p < 0.001$) and no significant changes from six to 12 weeks ($p < 0.47$) for both groups as shown in ***Figure 9***.

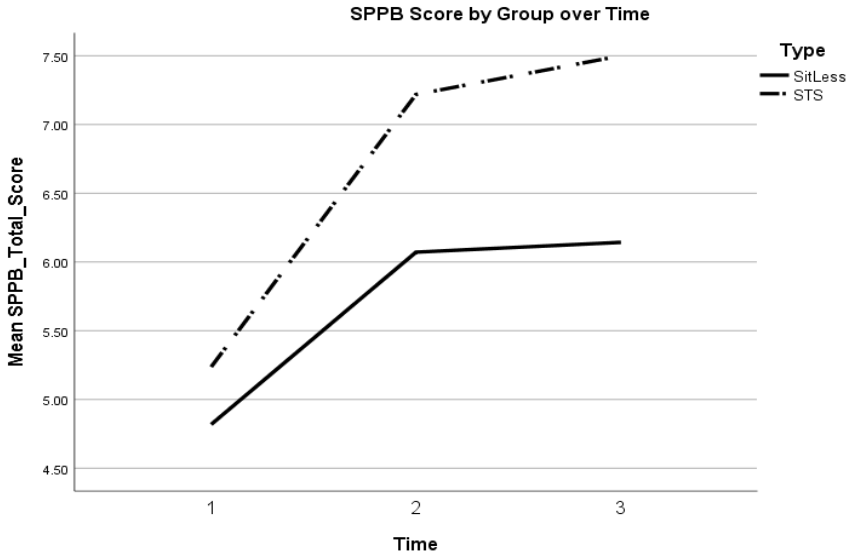


Figure 9. *SPPB by group over time points.*

From baseline to six weeks, 77% (n = 46) improved their SPPB score by at least one point, 15% (n = 9) experienced no change, and 8% (n = 5) decreased their SPPB by at least one point. From baseline to 12 weeks, 79% (n = 46) improved their SPPB score by at least one point, 12% (n = 7) experienced no change, and 9% (n = 5) decreased their SPPB by at least one point. These data are presented in ***Figure 10.***

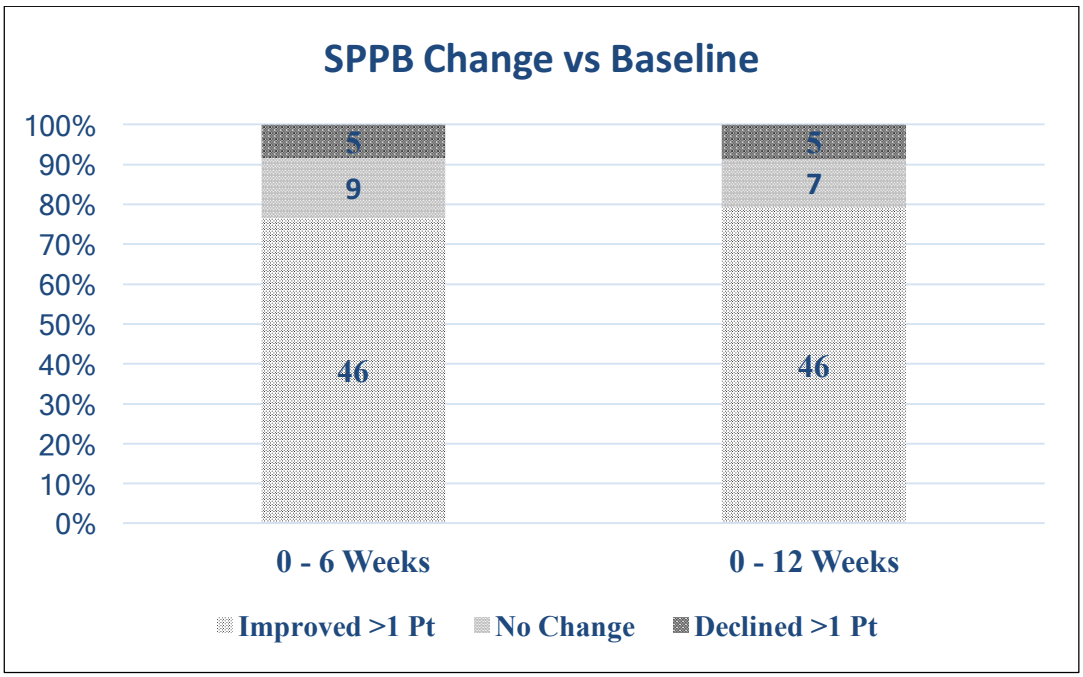


Figure 10. *Number of participants that changed SPPB score by ≥1 point, did not change, or declined by ≤ 1 point from baseline to six (n = 60) and 12 (n = 58) weeks.*

Balance

For balance, we fit an LMM to examine the efficacy of SUN on balance score (0-4 points), a subcomponent of the SPPB. We defined fixed main effects for time (0, 6, 12 weeks), group (SUN^{STS}, SUN^{SL}), and a group X time interaction. We included random effects of participants and sites. However, similar to previous models, the model did not converge and we removed the random effect for site. We also removed the non-significant interaction ($F(2, 120) = 0.96$, $p < 0.40$) during model refinement. Our final model was a REML model resulting in a significant main effect for time ($F(2, 122) = 35.1$, $p < 0.001$) and no significant main effect for group ($F(1, 66) = 2.1$, $p < 0.12$). There were significant increases from baseline to six weeks ($p < 0.001$) and no changes from six weeks to 12 weeks ($p < 0.49$).

Gait Speed

For gait speed, we fit an LMM to examine the efficacy of SUN on 4-meter gait speed score (0-4 points). We defined a fixed main effect for time (0, 6, 12 weeks), a fixed main effect for group

(SUN^{STS}, SUN^{SL}), and a group X time interaction. We included random effects for participants and sites. However, similar to previous models, the model did not converge. Thus, we removed the random effect for site and fit a REML model. There was no significant interaction (F (2, 123) = 1.9, $p < 0.17$). Thus, we removed the interaction during model refinement. Our final model showed a significant main effect for time (F (2, 124) = 12.8, $p < 0.001$) and no significant main effect for group (F (1, 71) = 2.6, $p < 0.12$). There were significant increases from baseline to six weeks ($p < 0.001$) and no changes from six weeks to 12 weeks ($p < 0.68$).

Chair Rise

For the chair rise, we fit an LMM to examine the efficacy of SUN on ability to stand from a chair five times (0-4 points). We defined a fixed main effect for time (0, 6, 12 weeks), a fixed main effect for group (SUN^{STS}, SUN^{SL}), and a group X time interaction. We included random effects of participants and sites. However, similar to previous models, the model did not converge. Thus, we removed the random effect for site and fit a REML model. During model refinement, we removed the non-significant interaction (F (2, 116) = 1.4, $p < 0.27$). Our final model showed a significant main effect for time (F (2, 118) = 8.02, $p < 0.001$) and no significant main effect for group (F (1, 68) = 0.97, $p < 0.33$). There were significant increases from baseline to six weeks ($p < 0.001$) and no changes from six weeks to 12 weeks ($p < 0.96$).

We further examined the chair rise by removing all of the participants who could not complete one chair rise (score = 0), allowing us to examine the efficacy of SUN to improve the ability to stand from a chair for those who could complete five chair rises (score 1-4). We defined an LMM with a fixed main effect for time (0, 6, 12 weeks), a fixed main effect for group (SUN^{STS}; SUN^{SL}), and a group X time interaction with random effects for participants and sites. However, similar to previous models, the model did not converge and we removed the random effect for site

and fit a REML model. There was no significant interaction (F (2, 65) = 0.30, $p < 0.75$). Thus, we removed the interaction during model refinement. The final model showed a significant main effect for time (F (2, 66) = 7.0, $p < 0.002$) and no significant main effect for group (F (1, 43) = 1.7, $p < 0.20$). There were significant increases from baseline to six weeks ($p < 0.002$) and no changes from six weeks to 12 weeks ($p < 0.95$).

Mobility: 8 foot up-and-go (8ft UG)

Means and SDs for time to complete the 8ft UG for each group at all time points are in **Table 9**. We fit a three-level LMM to examine the efficacy of SUN on mobility, as measured by the 8ft UG. We defined fixed main effects for time (0, 6, 12 weeks), group (SUN^{STS}, SUN^{SL}), and a group X time interaction. Four outliers (>2.58 SD's above mean) were removed (Weiner et al., 2003). We included random effects for participants and sites. The ICCs for site (ICC = 0.033) was low and the model failed to converge. Thus, we removed the random effect for site and fit a REML. There was no significant interaction (F (2, 113) = 1.05, $p < 0.35$) and this parameter was removed during model refinement. There was no significant main effect for time (F (2, 115) = 2.1, $p <0.13$) and no significant main effect for group (F (1,67) = 1.8, $p < 0.18$). The effect sizes (Cohen's *d*) computed for the 8ft UG were 0.2, 0.3, and 0.27 at baseline, 6, and 12 weeks, respectively (Table 10).

Depressive Symptoms: CES-D

We had a baseline mean score of 6.1 (SD = 4.6) with no difference between groups ($p < 0.84$). A score of greater than 10 indicates "depressed". Eleven (15.5%) had a score of >10 at baseline with no differences between groups ($SUN^{SL} = 5$, $SUN^{STS} = 6$; **Table 11**). We fit a LMM to examine the efficacy of SUN on depressive symptoms with fixed effects for time (0, 6, 12 weeks), group (SUN^{STS}; SUN^{SL}), and a group X time interaction. We first included random effects

for participants and sites. As with our previous models, due to low ICCs for sites (ICC = <0.001), the model failed to converge. We removed the random effect for site, and fit an REML model. There was no a significant group X time interaction (F (2, 119) = 0.03, $p = 0.97$). Thus, we removed the non-significant interaction in model refinement. The final model showed no significant main effect for time (F (2, 121) = 0.74, $p < 0.48$) and no significant main effect for group (F (1, 69) = 0.118, $p < 0.74$) ***(Figure 11).*** The effect sizes (Cohen's *d*) computed for the CES-D score were 0.04, 0.13, and 0.15 at baseline, 6, and 12 weeks, respectively (Table 11).

Table 11. *CES-D Scores of SUN Participants by Group*

	SUN^{STS}	**SUN^{SL}**	**Total**	**Cohen's *d***
Time Point	Mean (SD)	Mean (SD)	Mean (SD)	
Baseline	6.2(4.8)	6.0(4.3)	6.1(4.6)	0.4
95% CI	4.7 to 7.8	4.5 to 7.5	5.0 to 7.2	
Mid-Intervention	6.4(4.4)	5.8(4.7)	6.1(4.5)	0.13
95% CI	4.8 to 8.0	4.0 to 7.6	4.9 to 7.2	
Post-Intervention	5.8(5.4)	5.1(4.1)	5.5(4.8)	0.15
95% CI	3.7 to 7.8	3.5 to 6.7	4.1 to 6.7	

Note. CES-D = Center for Epidemiologic Studies Depression Scale;
CI = Confidence Intervals

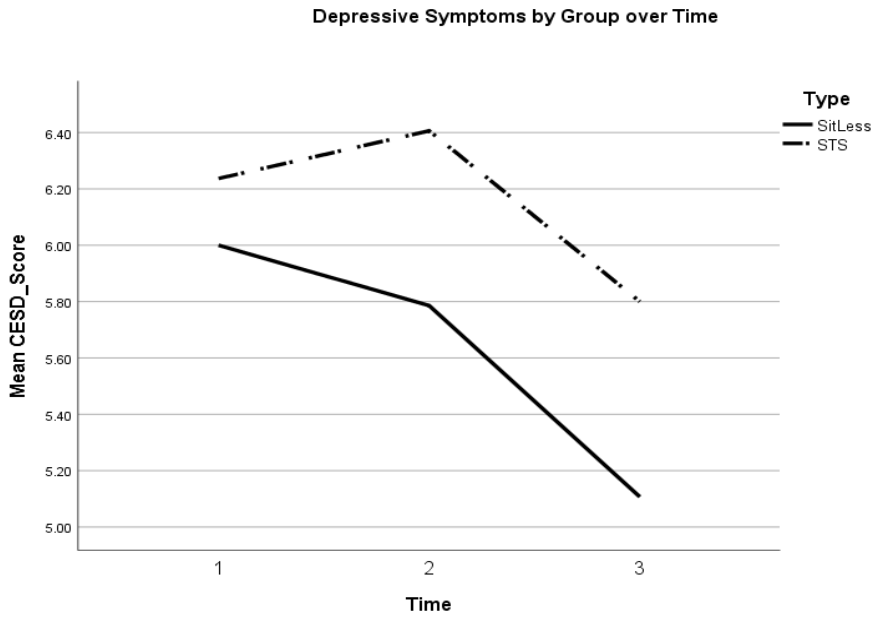


Figure 11. *CES-D by group over time points.*

Participant Compliance and Retention

Of the 58 participants to complete all three measurements of the intervention, 57 (96.6%) completed > 67% of the health coaching sessions. There was 15.5% and 18.3% attrition over six, and 12 weeks, respectively. The most common reason to dropout was a health complication (n = 8) such as a fall or surgery. The others felt they were too busy to meet weekly and participate in the study (n = 5). There were no significant differences between in any variables with those who who completed the study and those who did not complete (i.e., dropouts) (**Table 7**).

Adverse Events

There were 29 total adverse events (AE). Five (17%) discontinued the study due to the AE due to surgery (n=2) and hospitalized falls (n=3). Eleven of the 29 were serious (falls (n=6), surgery (n=2), cardiovascular disease related signs or symptoms (n=3)). No adverse events were experienced during any in-person contact with participants during measurements or health

coaching sessions, simply self-reported as an event between health coach visits. Details of the adverse events are reported by site and group in Appendix A, **Table A9**.

Intervention Satisfaction

Participant satisfaction with the components of the SUN intervention is reported in **Table 12** by group. Participants in both groups were most satisfied with the in-person health sessions and least satisfied with the workbook materials. Nearly all participants (n = 54; 93%) rated the length and content of the in-person health coach sessions as either a 4 or 5 out of 5 (0 = not satisfied; 5 = very satisfied). Some participants indicated the phone calls were a good reminder and they appreciated the shorter meeting, while others found the phone calls difficult due to a hearing and/or technology barrier. There were no differences between groups with any components of the intervention (*ps* > 0.05), except for the workbook materials. The SUN^{SL} group (Mean = 3.0 on a 5-point scale) rated this component of the intervention significantly lower than the SUN^{STS} (Mean = 4.2) group ($p < 0.001$).

Table 12. *Results from SUN Intervention Satisfaction Survey*

	SUN^{STS} (N = 30)		SUN^{SL} (N=28)		*p-value*
SUN Component	**M (SD)**	**% 4 or 5 / 5**	**M (SD)**	**% 4 or 5**	
In-Person					
Length of Sessions	4.9(0.3)	100	4.6(0.7)	85	0.06
Content of Session	4.8(0.41)	100	4.6(0.8)	82	0.27
Graphical Feedback	4.6(0.73)	86	4.3(0.9)	75	0.14
Other Materials (goal setting sheet, prompts, etc)	4.2(1.0)	75	3.0(1.6)	32	0.001
Number of Sessions	4.7(0.5)	93	4.4(1.1)	82	0.28
Phone Calls					
Length of Sessions	4.8(0.5)	96	4.4(1.1)	82	0.11
Content of Session	4.7(0.6)	93	4.4(1.1)	75	0.12
Number of Sessions	4.7(0.6)	93	4.4(1.1)	75	0.13

The Results chapter, in part, are currently being prepared for submission for publication. Thralls, Katie J.; Levy, Susan S. The dissertation author was primary author of this material.

Discussion

Overview

We assessed the efficacy of a 12-week intervention with two groups to improve specific sedentary behavior (SB) goals (i.e., either increase STS transitions (SUN^{STS}) or reduce total sitting time (SUN^{SL})) over six and 12 weeks. We hypothesized that each group would significantly improve their respective SB change goal at six and 12 weeks and not change with respect to the other group's goal. Contrary to our hypothesis, both groups significantly decreased sitting time (~1.3 ± 0.3 hours/day), decreased percent of sitting during waking hours (~3.6 ± 2.1% per day), and increased standing time (~0.5 ± 0.2 hours/day) at six weeks; these improvements were all maintained at 12 weeks. Supporting our hypothesis, the SUN^{STS} group significantly increased STS transitions per day at six weeks (5.4 ± 4.1 per day) and there were no changes in STS per day in the SUN^{SL} group. Further, we assessed the efficacy of the SUN intervention on physical function and mobility over six and 12 weeks and differences between intervention groups (SUN^{STS}, SUN^{SL}). Supporting our hypothesis, both groups improved their physical function from baseline to six weeks, and maintained this improvement at 12 weeks. Contrary to our hypothesis, there were no changes in either group for mobility at six or 12 weeks compared to baseline.

Sedentary Behavior

Our sample spent a greater percent of their waking hours being sedentary (73.8%) than reported for the general population of older adults (65%) (Evenson et al., 2012). Other cross-sectional and prospective studies in older adult living facilities have also reported > 70% of waking hours as sedentary (Chan et al., 2016; Harvey et al., 2015; Leung et al., 2017; Ried et al., 2013). Previous older adult SB interventions, vary in levels of SB variables, and not all studies report STS transitions. Our baseline sitting (11.1 ± 1.7 hrs/d), standing (3.3 ± 1.6 hrs/d), and stepping (1.0 ±

0.4 hrs/d) time were similar to the values reported by Kerr et al. (2016), who reported 11.3, 3.3, and 1.3 hours per day, respectively. Lewis et al. (2016) and Rosenberg et al. (2015) both reported lower baseline SB of approximately 9 hours per day of sitting, representing 54% and 67% of waking hours, respectively.

Three interventions reported STS transitions with the activPAL; two of those studies had baseline values of nearly 40 STS transitions per day, using the device default 10-second value to detect changes in posture (Kerr et al., 2016, Rosenberg et al., 2015). The other study reported higher baseline STS transitions (55/d) but they did not report the data processing method (Fitzsimmons et al., 2013). Our sample also had 55 STS transitions per day. We used 1-second as the value to capture STS transitions that were shorter than 10-seconds, which at least partially explains higher STS transitions relative to previous studies.

Compared to the one other SB intervention of a similar length (i.e., 12 weeks) in older adults who experienced no changes in SB, SUN significantly reduced SB (Gibbs et al., 2016). When compared with SB interventions of shorter duration, our findings at mid-intervention (6 weeks) and post-intervention (12 weeks) are comparable. Lewis et al. (2016) conducted a 6-week intervention study with one group of an older adult sample younger than SUN (i.e., M_{age} = 72 ± 6.5yrs) and found comparable changes; their sample significantly decreased sitting by 51 minutes/day and increased standing by 39 minutes/day. They did not report STS transitions. Rosenberg et al. (2015) published the only other intervention with a mid- and post-intervention measurement. They also included weekly individual health coaching with a combination of in-person and phone call sessions. Although the intervention was conducted over a shorter time frame, their older adult sample also significantly decreased sitting time (by 27 minutes/d) and increased standing time (by 24 minutes/d) at mid-intervention (4 weeks) that was maintained at

post-intervention (8 weeks), while they also continued health coaching sessions. They reported no significant changes in STS transitions at any time point, similar to our SUN^{SL} group. In comparison, our sample decreased sitting time to a greater extent (decrease of 78 minutes/d) than the sample in Rosenberg et al. (2015). However, similarly, SUN also maintained SB changes with on-going weekly contact from mid-intervention (6 weeks) to post-intervention (12 weeks). The maintenance seen in both intervention studies, rather than a continued improvemnt in the reduction of SB time, may be due to several reseasons. First, both studies had more in-person visits in the first half of the study than the second half that may illicit greater behavior changes than the phone call sessions that were from mid-intervention to post-intervention. Another explanation in our lower functioning sample is that maintenance from six to 12 weeks is due to physical limitations and challenges of being of lower physical function.

Only one other study incorporated two intervention arms with the same two distinct SB goals as SUN: to increase number of STS transitions per day (SUN^{STS}) or to decrease total time spent sitting per day (SUN^{SL}) (Kerr et al., 2016). In this previous intervention, both groups only improved in their specific goal resulting in a significant decrease of sitting (130 minutes/day) in their reduced sitting group and a significant increase (13 STS/day) in STS transitions in their STS group. Different from our study, these SB changes are higher than those found in the current study and neither group also significantly changed in the other group's respective goal. Also different than SUN, both groups in Kerr et al. (2016) significantly increased their stepping time (by ~ 10 minutes). Based on these prior results, we anticipated a similar outcome with our two intervention groups. Retrospectively, this difference in both fewer minutes of total SB time and fewer STS transitions may be attributed to the differences in our sample (i.e., older and of lower physical function) as well as the length of the intervention. Kerr et al. (2016) had a sample of 30 working

and non-working community-dwelling older adults (M_{age} = 61 ± 6.0yrs) over two weeks. Their greater improvements in each variable, compared to our study, were likely due to a younger, higher functioning sample and shorter study. A two-week study allows participants to stay focused on the goal to complete the study with large temporary changes. Whereas a 12-week study requires a long-term habitual mindset that also potentially reflects lasting habitual changes over time. It is possible our sample had greater improvements in the second and third weeks of the study that leveled out by weeks six and then 12 to reflect more long-term habitual changes.

The only difference between our two SUN groups in changes in activPAL variables, was that our SUN^{STS} group significantly increased their STS transitions (i.e., by 5/d) by 10% from their baseline value to six weeks but no changes from baseline to 12 weeks, while the SUN^{SL} group experienced no changes in STS transitions at any time point. We show that participants in the SUN^{STS} group were able to significantly increase STS transitions per day, although over time they either reverted back to their original STS transition behavior or improved other aspects of SB that are not captured by maintaining STS transitions. For example, examining STS transitions with results in sitting/standing time together, these data suggest that participants are standing for longer bouts throughout the day at six weeks and 12 weeks, leading to a decrease in STS transitions while maintaining their reduction in sitting time and increasing their standing time. In our moderate-to-low functioning sample, the effort to stand and sit is fatiguing and thus, once standing, they remain standing for longer. At first (from 0 to 6 weeks) participants could not stand for long periods, resulting in an increase in STS transitions. However, from six to 12 weeks, the SUN^{STS} participants were able to stand for longer bouts in order to maintain their increase in standing time (decrease in sitting time) from six to 12 weeks and reduce their STS transitions back to baseline values. Although health coach sessions and activPAL graphical feedback (at baseline and six weeks)

focused on STS transitions and cued participants to increase the number of "STS transitions", this sample continued to stand for longer and followed the same SB trends as the SUN^{SL} group. Two other interventions reported STS transitions and both studies reported a significant reduction in sitting but no changes in STS transitions over time (i.e., 2 and 8 weeks) (Fitzsimmons et al., 2013; Rosenberg et al., 2015). Further, in comparison to standing, which is a familiar behavior, the behavior of a STS transition is an unfamiliar and unusual concept for individuals and may require additional cues, individualized reminders, or strategies to target and isolate this specific behavior.

In summary, the changes in activPAL variables support the efficacy of the SUN intervention to reduce SB over six weeks and to maintain that level to 12 weeks in older adults of moderate-to-low physical function. These data show that both intervention groups significantly decreased sitting by over one hour/day with most of that time being allocated to standing as shown by a significant increase in standing time and no significant changes in stepping in either group.

Physical Function

In addition to the changes in SB, our study also showed significant improvements in physical function from baseline to six weeks with maintenance from six to 12 weeks, as measured by the SPPB. Prior to SUN, only two older adult SB interventions examined physical function before and after the intervention, also measured by the SPPB. Both studies were in a younger high functioning sample, with a baseline SPPB score greater than 10.5 (Gibbs et al., 2016; Rosenberg et al., 2015). Rosenberg et al. (2015) reported significant improvements in gait speed, but no improvements in the other two components (i.e., balance and chair rise) or the total score. Gibbs et al. (2016) reported significant improvement in SPPB score (i.e., 11.1 to 11.6). However, this change in total score was only due to improvements in the chair stand measure, with no changes in the balance or gait speed scores. The statistically significant improvements in the SPPB total

score as well as all three SPPB subcategories seen in SUN were to some degree, perhaps due to moderate-to-low baseline function of the sample, suggesting that the SUN approach may be particularly useful in lower functioning older adults. Further, the improvements from baseline to six weeks (1.5 points) and 12 weeks (1.8 points) were not only statistically significant but are also a clinically meaningful change and considered a substantial meaningful change (> 1.0) in physical function, as suggested by Perera et al. (2006).

While we did not see a statistically significant interaction between our intervention groups over time for physical function, we found an incrase in effect size from small (d = 0.21) to medium (d = 0.55) at 12 weeks. Increases in effect sizes were also consistently increased for all three of the sub tests for the SPPB, favoring the SUN^{STS} group. This finding may suggest there were larger improvements in the SUN^{STS} that may be statistically signifincat in a larger sample and warrants more examination in a future larger intervention trial.

Similar to changes seen in the study by Gibbs et al. (2016), our sample improved in the chair stand over six weeks. However, since nearly half (n = 31; 44%) of SUN participants at baseline could not stand from a chair without using their upper body strength, we further examined the measure with just participants who were able to complete the chair stand (i.e., stand from a chair with arms across shoulders). Interestingly, we found six (19% of those who could not stand without upper body support) participants who could not stand from a chair at baseline were able stand from a chair by six or 12 weeks without their arms, all of which were in the SUN^{STS} group. Alternatively, there were no participants in the SUN^{SL} group who were able to complete the chair stand at six or 12 weeks who were unable at baseline. Our sample is too small to statistically analyze these data, however, these improvements in chair stand in addition to the effect sizes may suggest that the significant increase in STS transitions at six weeks in the SUN^{STS} group

contributed to these improvements. The increase in STS transitions may increase leg strength to complete a chair stand without using assistance or the weekly health coaching sessions with STS transition cues, which were similar to the chair stand test, motivated the participant to use more of their leg strength during their STS transitions in daily life rather than rely on their arms or walkers to aid them in getting up.

Significant improvements in 4-meter gait speed were also found from baseline to six weeks in our sample and maintained at 12 weeks. Measures of usual gait speed alone from various lengths are associated with poor health and function, predictive of disability, and predictive of five or 10-year survival (Kuys, Peel, Klein, Slater, & Hubbard, 2014; Studenski et al., 2003; Studenski et al., 2011; Tsutsumimoto et al., 2016; Van Kan et al., 2009). Perera et al. (2006) also reported small and substantial meaningful changes in 4-meter gait speed to be 0.05 meters per second (m/s) and 0.1 m/s, respectively. Our sample significantly increased from 0.57 m/s to 0.66 m/s (0.09 m/s change), supporting that these data are not only statistically significant but also a clinically meaningful improvement. This improvement is similar to improvements reported in a home-based physical activity study (Helbostad et al., 2017) in frail older adults who improved by 0.06 to 0.07 m/s. Further, 0.60 m/s has been used as a threshold cut-off for "slow gait" speed, with a study reporting significantly more hospitalizations in slow (<0.6 m/s) compared to intermediate (0.6-1.0 m/s) or fast (1.0 m/s) walkers (Studenski et al., 2003). Our study sample's average gait speed crossed that threshold, starting at <0.6 m/s and improving to >0.6 m/s. Longer follow-up would be needed to examine the potential of SUN to reduce longer term outcomes, such as hospitalizations.

Our study sample also improved balance scores at six weeks that were maintained at 12 weeks. Standing for longer periods of time requires more leg strength; it requires a person to engage muscles as well as activate neuromuscular pathways that may contribute to better stability

and balance. Thus far no published study has specifically examined SB and balance. There are now more objective forms of measuring balance with center of pressure measures, rather than observation of standing positions as in the SPPB measure. Future SB studies may want to further examine balance with an objective measure and a potential way to improve balance and decrease falls (Levy, Thralls, & Kviatkovsky, 2018).

While limited SB interventions have examined changes in SB and physical function, there are physical activity (PA) interventions that have similar changes in physical function. PA interventions, including studies with older adults of moderate-to-low physical function, have shown to improve physical function (De Labra et al., 2015; Giné-Garriga et al., 2010; Giné-Garriga et al., 2014; Levy, Thralls, Goble, & Krippes, 2018; Pahor et al., 2006; Pahor et al., 2014; Silveira et al., 2013; Vestergaurd, Kronborg, & Puggaard, 2008). A PA intervention with a comparable lower functioning older adult sample reported similar improvements to the current study in SPPB from 7.5 to 8.7 points after six months of three times per week multi-component PA session (Pahor et al., 2006). Comparable to our study, where 77% (n = 46) improved their SPPB by at least one point, this PA intervention also reported that 67% (n = 133) of their PA group improved their SPPB score by at least one point (Pahor et al., 2006). Our sample had a slightly lower baseline which may be why we had a greater amount improve by at least one point.

While PA interventions have been shown to be effective to improve physical function, research supports that < 3% of older adults meet PA guidelines when PA is measured with objective instruments (Evenson et al., 2012). Many barriers that keep older adults of lower physical function from engaging in PA (Bethancourt, Rosenberg, Beatty, & Arterburn, 2014). The majority of CCRCs, including all four of the facilities in the current study, recognize the benefit of PA and offer complimentary PA classes as well as access to a fitness room. However, < 10% of the

residents attend PA classes, suggesting that barriers beyond cost or travel are hindering PA class attendance. Based on the principle of progressive overload, PA requires proper progression with proper rest and adaptations over time that allow individuals to increase in volume or intensity. With PA, a proper modifiable and individualized progression is necessary. Alternatively, reducing SB is of lower intensity. While there is a degree of building stamina to stand longer, the behavior of standing itself is doable from the beginning of the program. Thus, SB health coaching is focused on strategizing how, where, and when to incorporate standing rather than a personal trainer focusing on the proper load, volume, and intensity of a PA program. To separate the effects of PA and SB on physical function, we excluded residents attending > 1 PA class per week. Also, it is important that there were no changes in stepping time or steps in SUN, supporting that improvements made in physical function in SUN were not clouded by changes in PA. The current study adds to the body of knowledge by giving an additional modifiable strategy to improve physical function and extend independence.

Mobility

Unlike physical function and contrary to our hypothesis, we found no changes in mobility, as measured by the 8-foot up-and-go (8ft UG). The 8ft UG is a complex assessment requiring several combined parameters of fitness, including lower body strength, reaction time, agility, balance, and speed (Rikli & Jones, 1999). The assessment represents being able to move about the house and to change directions safely and efficiently. In this lower functioning sample, no changes may be considered an "improvement", as a true control group may have significantly declined in this assessment after 12 weeks with no intervention, as seen in previous PA interventions with a true control group (Cadore, Cadore, Sinclair, & Izquierdo, 2008). While no SB interventions have also reported mobility, multicomponent PA interventions have shown significant improvements in

the 8ft UG and timed-up-and-go (TUG) (i.e., a comparable test to the 8ft UG) (Cadore et al., 2008; Kim et al., 2015; Levy, et al., 2017). In a study by Kim et al. (2015), frail older women significantly improved their TUG from 9.63 seconds to 7.98 seconds after 12 weeks of a multicomponent exercise program (2x/wk for 60 minutes) (Kim et al., 2015). Levy et al. (2018), in a community-dwelling sample of older adults, also showed statistically significant improvements in the 8ft UG after 3 months (2x/wk for 60 min) of a multicomponent PA program. However, other studies have reported no changes in mobility. Latham et al. (2003) found no changes after 12 weeks of a home-based exercise program focused on resistance exercise in frail older adults (3x/wk). This null finding may have been due to a focus on one component of fitness (i.e., lower body resistance exercise), rather than multicomponents like the other interventions that did see improvements. Cadore et al. (2013) had comparable baseline 8ft UG scores to our study at 19.9 ± 8.0 seconds in their frail older adult sample. Their PA group, after receiving 12 weeks of a multicomponent fitness program (2x/wk), improved by over 1 second (18.8 seconds), while their control group regressed from 18.4 seconds to 21.6 seconds. Thus, improvements in this complex assessment, in this lower functioning demographic, are possible but may need a program specfically targeting multiple components of fitness.

Depression: CES-D

No significant changes in depression were found for either group of the SUN intervention at either six or 12 weeks. No change from the baseline mean of 6.1 (SD = 4.8) is likely due to the wide variability in our sample in this outcome. This scale is out of 30 points with >10 points indicating “depressed”. While our sample had a mean of 6.1, showing low depressive symptoms, the high variability indicates we had participants with a wide range of depressive symptoms. This finding is similar to a 12-week PA study in CCRCs who also had no significant changes in

depression (Rosenberg et al., 2009). However, previous studies have shown high amounts of SB to be associated with depression (Leung et al., 2015; Rosenberg et al., 2016). We feel emotional health was improved but not captured through this measure in this sample. Thus, future studies may want to add a measure to capture benefits to emotional health, such as positive affect.

SUN Intervention Retention, Compliance, and Satisfaction

We retained 82% of our sample over 12 weeks, one of the strengths of our study. This retention is also comparable to retention of another 12-week PA intervention conducted in CCRCs (77%) (Rosenberg et al., 2009). SUN was longer than the other effective SB interventions but still comparable in retention to Rosenberg et al. (2015) who had 81% retention over eight weeks and slightly higher than in the study by Fitzsimmons et al. (2013) with 67% retention over two weeks.

We anticipated a higher dropout rate due to the lower functioning sample. However, we reduced participant burden in several ways to maximize retention. First, we waterproofed the devices to be worn continuously and only required the activPAL measure at the three measurement periods. The waterproofing and continuous wear protocol relieved participants of any extra instructions related to removing and re-applying the device, as still done with the hip-worn Actigraph physical activity monitors. Also, by the end of the study, participants indicated they were glad to be done wearing the activPAL and they may have dropped out earlier if they had to wear it more often. While it would have been helpful to have objective SB data weekly, it would not be realistic to require participants to wear the device every week. Further, we reduced transportation or forgetfulness barriers by meeting participants in their living facility and allowing them to readjust weekly times if needed. We also gave weekly appointment reminder calls prior to their sessions. Continuing to consider participant burden in the design and implementation of interventions is necessary to maximize retention and compliance.

Older adults from previous SB interventions indicated a high acceptability and satisfaction with direct individualized feedback from the activPAL data (e.g., a graph showing when and how long they sit or take STS transitions) (Gardiner et al., 2011; Kerr et al., 2016; Rosenberg et al., 2015). Similarly, our participants indicated this individualized feedback increased their awareness and was helpful to strategize when and where to change their behavior and over 80% rated this intervention component as 4 or 5 out of 5 as being very helpful (5 = very helpful on a 0 to 5 point scale). Most all of our participants enjoyed meeting with their health coach in-person while there was mixed feedback about the phone call sessions. Phone call sessions were difficult for some participants with hearing impairments as well as participants unfamiliar with technology. However, the phone call also inevitably was a reminder to the participant about the study and their sedentary behavior goals. Rosenberg et al. (2015) also reported that 19% of their sample did not use their workbook activities. This category (i.e., workbook activities) also had lower satisfaction from our participants, particularly for the SUN^{SL} group. We feel that the SUN^{SL} group gave a significantly lower rating for the workbook activities because they quickly and easily understood the importance of reducing sitting time and felt no need to do workbook activities related to standing up. Rather, STS transitions were a new concept and an unfamiliar behavior that was introduced to the SUN^{STS} group and the workbook activities may have seemed more helpful. Overall, participants were satisfied with the SUN intervention, however additional ways to individualize the intervention strategies for each person's lifestyle and preferences will help improve satisfaction and may lead to greater behavior change and longer maintenance.

activPAL Compliance and Satisfaction

As one of our secondary aims, we felt it was important to examine and report the compliance and satisfaction of the activPAL device for the design of future interventions and

behavior change strategies. All SUN participants completed a valid wear for their baseline week and most (75%, n = 53) completed the sleep/wake logs, suggesting this is an acceptable and feasible form of measurement in lower functioning older adults. A previous study with a lower functioning sample in an older adult living community had 45% (n = 14) return sleep/wake logs and 20% lost devices (n = 6) (Reid et al., 2013). However, their sample was of slightly lower physical function (SPPB = 4.0) and higher sedentary time (>12 hours per day; 85% of waking hours). All of our participants provided valid wear time at baseline and we had no lost devices at baseline. Over the 12-week study, there were two device malfunctions and three lost devices. The few devices that fell off of SUN participants may have been due to skin lotions or soaps that were used prior to attachment. Even though four participants indicated they had an irritation (e.g., small rash or skin reaction) from the adhesive at baseline, all four rewore the device for follow-up measurements and did not have another skin issue. This irritation may have been due to outdoor climate of that particular week (e.g., high heat and humidity) or possible skin lotions or soaps that reacted with the adhesive. These challenges are similar to challenges with younger adults as reported in Edwardson et al. (2017). Also, the waterproof and 24-hour wear period is simple for participants, which results in higher compliance than the gold standard PA device, a hip-worn accelerometer that is removed for water immersion and sleep (Matthews et al., 2012). Further, with a continuous wear protocol, this device seems to be easy for participants to forget which may allow for less of a reactivity bias and be more likely to reflect usual behavior. Several participants indicated they forgot they were wearing the device. Lastly, while the satisfaction survey indicated a high acceptability, satisfaction, and willingness to rewear the device, we did not reassess their satisfaction with the device after the study. Participants were relieved to be done wearing the device in our last measurement and it seemed their satisfaction and willingness to wear the device

declined. Interventions should not expect the results from our satisfaction survey at baseline and compliance to be withstood for several weeks at a time over a larger or longer study.

Strengths

Stand Up Now was designed based on previous SB interventions in older adults to extend the research in this area. SUN extends the current interventions with a longer study and larger sample size to demonstrate the efficacy to reduce SB in older adults. We also targeted a population with lower physical function and examined the efficacy of SUN on health outcomes of physical function and mobility. Even with a lower functioning sample, we were able to retain 82% of our sample over 12 weeks with a high attendance (i.e., 80% attending > 67% of the health coach sessions). Further, our research assistants were trained in all study measurements. Our measurement research assistants differed from our health coaches to minimize meausurement bias. Also, health coaches were allocated to specific SUN intervention groups. Our measures included the gold standard (i.e., activPAL) measurement for SB and validated objective measures for physical function and mobility. Additionally, our study design with three time points allowed us to conduct analyses using all available data. We feel SUN will contribute to a larger understanding of SB measurement, behavior change strategies, and its relationship to the health of physical function to extend independence in older adults.

Limitations

While we have shown the efficacy of our intervention to reduce SB and improve physical function in our sample, we recognize several limitations to be considered with our conclusions. First, there was no control group. As with previous SB interventions, none of which incorporated a control group, it is unknown how participants not receiving the intervention would have compared to our SUN participants. Due to the small number of interventions in this field and none

thus far in this population, we felt it was important to maximize the number of participants receiving the SB intervention to gain an understanding of the efficacy of the intervention on the outcomes of SB and physical function prior to conducting a larger controlled study. In our sample of lower physical functioning older adults it is likely that a comparable sample not in the intervention would have continued to decline in physical function level, as seen with PA studies that have included a true control group (Cadore et al., 2013; Fairhall et al., 2013). Fairhall et al. (2013) reported a significant decline in physical function in their control group (5.7 to 4.7 points on SPPB). Another 12-week PA intervention in a similar sample of frail older adults showed a significant improvement in their intervention while their control group significantly regressed in a timed up-and-go test (Cadore et al., 2013).

Also, with three measurement weeks of wearing the activPAL, we do not know the sedentary behavior of the participants for the weeks in between measurements. It is possible STS transitions were higher in weeks that participants did not wear the device. If the activPAL was worn over the full 12-week study we may have seen greater differences between the intervention groups in sedentary behavior variables.

Additionally, each health coach self-monitored their ability to complete all components of each session with the health coach record sheets. If sessions were auditorily recorded or an outside observer completed the health coach record sheet, there would be additional accountability to assure the intervention fidelity was maintained during each health coach session. Further, an outside observer or auditory recording would have allowed us to examine qualitative data with the targeted BCTs used such as goal setting, action planning, use of prompts, and individualized feedback. This additional information would help understand which BCTs were most effective to change behavior in this sample and CCRC setting for future behavior change interventions.

Further, participants may have reduced SB due to changes in self-efficacy. However, without a measure of self-efficacy we cannot determine which constructs of SCT and which BCTs influenced behavior changes in our sample. Future interventions may want to incorporate ways to disentangle which BCTs were effective to change behavior in this population.

Lastly, our sample reflected the demographics of the facilities in which they were conducted, however, the majority of participants were female, educated, and Caucasian. Further, with only four sites and little variability between sites, it is difficult to translate results to other settings and demographics. Thus, future studies are needed to focus on reaching older adults of different demographics and settings where strategies to effectively reduce SB may differ. Although limited to two intervention arms, four sites, and a limited demographic, this study serves as a stepping stone with sufficient seed data to conduct a larger scale multi-site randomized controlled trial.

Considerations for Future Research

Stand Up Now provides a foundation for future research to build on to continue to improve the health and quality of life of individuals through SB change. Future SB interventions are needed to examine additional intervention strategies to reduce SB and maintain long-term changes. Studies are now starting to examine creative intervention design strategies with "just in time" adaptive designs that specifically target different intervention strategies depending on the individual and on their current behaviors (Muller, Blandford, & Yardly, 2018). These designs and intervention strategies may avoid monotony and result in continued improvements. Also, Brach et al. (2018) reported significantly higher levels of SB (1.7 hours more) in older adults living in designated older adult housing than in older adults living in private homes/apartments. A *Sedentary Behavior Workshop* with experts in the field identified the need for multi-level SB interventions across

different contexts and life phases (Manini et al., 2015). As designated older adult living communities continue to expand, future interventions should design and examine the efficacy of sustainable intervention strategies across different levels of the socioecological model (e.g., institutional, environmental). For example, pending staff and building regulations, reminder signs around the building, standing break reminders during social events (e.g., meals, bingo, bridge) or standing desk/table options in community areas for those capable of using them, may reduce SB and extend independence in this setting. A multi-level intervention may help reduce staff burden, overhead cost, and lead to long-term behavior changes.

Now that we have demonstrated efficacy for SUN to reduce SB, without changing PA, and improve physical function but not mobility, an ideal situation would be for older adults to both increase PA and decrease SB to optimize health. As noted earlier, mobility may need a more specific multicomponent PA program. Further, recent research shows that even higher amounts of light intensity PA is associated with better physical function (Lacroix et al., 2019). The 2018 Physical Activity Guidelines for Americans recommend to "move more and sit less" and several studies are now examining improvements in both behaviors and health in this population (Gine-Garriga et al., 2017; US DHHS, 2018). A reasonable next step after a SB intervention, such as SUN, would be to continue to maintain a reduction in SB and begin adding PA that incorporates more movement and multiple components of fitness. Future studies should continue to integrate both behaviors to examine feasible and sustainable behavior change strategies as well as long-term health outcomes.

We have shown in the current study that the gold standard activPAL device is acceptable in a lower functioning older adult sample. Thus far, SB studies have adopted PA wear time protocols for free-living measurements, administering the device for seven days with a valid wear-

time of four days (10hr/day), including one weekend day. However, studies have not specifically determined the needed valid wear days for all activPAL SB variables (Edwardson et al., 2017). Further, most studies have used the default time of 10 seconds as the minimum time to detect a change in posture. However, for this population and this intervention's specific STS transition goal, it is important to capture STS transitions that are not held for a full 10 seconds. Thus, we used a time of one second to detect a change in posture. Future studies with direct observation are needed to determine a standardized protocol for data wear time and processing with the activPAL device in this population.

Lastly, it is unknown how participants in the current or previous SB interventions sustained or changed behaviors after the intervention was completed. Clough-Gorr et al. (2008) reported that those who indicated a modification or inability to walk a half mile were nearly twice as likely to have a fall in the next year compared to those who indicated no difficulty. Wolinsky et al. (2005) reported that those who indicated a modification in stooping, climbing stairs, or walking a half mile had a significantly higher risk of inability to complete that movement less than two years later. These values would apply to about half of our participants. However, longer follow-up assessments and a control condition would be needed to determine if these rates were lower among our participants compared to those not receiving the intervention. Larger randomized controlled trials with follow-up on long-term outcomes such as hospitalizations, falls, health-related medical costs, and quality of life are needed to determine long-term changes and health.

Conclusions

Stand Up Now extends the current understanding of sedentary behavior interventions in older adults and the role of changes in sedentary behavior on physical function, an indicator of independence and quality of life. Prior to SUN, the longest effective sedentary behavior

intervention in older adults included 25 participants followed for eight weeks with older adults of high physical function (Rosenberg et al., 2015). SUN demonstrated the efficacy to recruit, retain, and implement a sedentary behavior intervention in older adults of moderate-to-low physical function, using the activPAL device. Most importantly, SUN supports the efficacy to reduce and maintain reductions in sedentary behavior as well as make clinically meaningful improvements in physical function in older adults of moderate-to-low physical function.

Appendix A

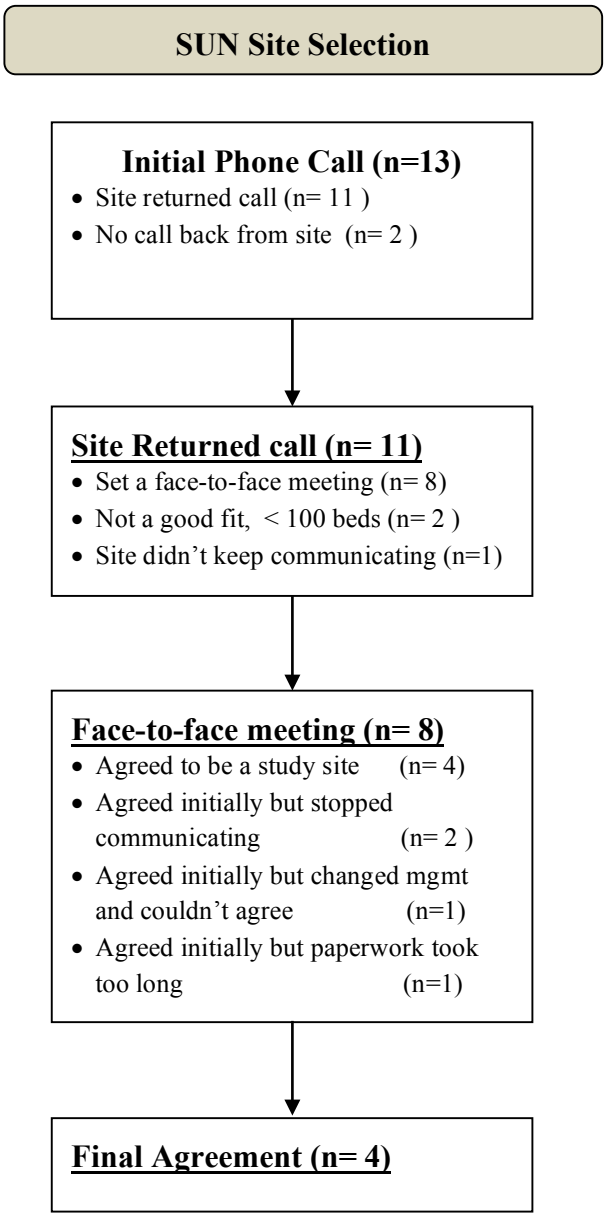


Figure A 1. *Site selection process*

Table A 1. *Baseline Descriptives of SUN Participants by Group*

	SUN^{STS} (N = 38)			SUN^{SL} (N=33)			SUN (N=71)	Group Differences	
	STS-A (N = 22)	STS-B (N = 16)	Combined	SL-A (N= 21)	SL-B (N=12)	Combined	TOTAL	Group	Site
Age (years)	89.8 (3.6); Median: 90	82.4 (7.3); Median: 82	86.8 (6.8); Median: 88	86.6 (7.0); Median: 88	87.3 (6.5); Median: 88	86.7 (6.5); Median: 88	86.8 (6.6) Median: 88	0.97	0.007
Female (%)	86.4 % (N=19)	81.3% (N = 13)	78.8% (n=26)	85.7% (N=18)	66.7% (N=8)	84.2% (n=32)	81.7% (N=58)	0.556	0.501
Ethnicity*								0.573	0.42
Caucasian	81.8% (n=18)	100% (n=16)	90.9% (n=30)	90.5% (n=19)	91.7% (n=11)	89.5% (n=34)	90.1% (n=64)		
Hispanic	4.5% (n=1)					2.6% (n=1)	1.4% (n=1)		
Native American	13.6% (n=3)		6.1% (n=2)	9.5% (n=2)		7.9% (n=3)	7.0% (n=5)		
African American	4.5% (n=1)					2.6% (n=1)	1.4% (n=1)		
Other			3.0% (n=1)		8.3% (n=1)		1.4% (n=1)		
Education								0.085	0.308
High School	31.8% (n=7)	18.8% (n=3)	12.1% (n=4)	14.3% (n=3)	8.3% (n=1)	2.3% (n=10)	19.7% (n=14)		
Some College	31.8% (n=7)	37.5% (n=6)	18.2% (n=6)	23.8% (n=5)	8.3% (n=1)	34.2% (n=13)	26.8% (n= 19)		
Completed	18.2% (n=4)	31.3%(n=5)	30.3% (n=10)	28.6% (n=6)	33.3% (n=4)	23.7% (n=9)	26.8% (n=19)		
Graduate School	18.2% (n=4)	12.5% (n=2)	39.4% (n=13)	33.3% (n=7)	50% (n=6)	15.8% (n=6)	26.8% (n=19)		
Marital Status								0.103	0.301
Widowed	77.3% (n= 17)	50% (n=8)	48.5% (n=16)	42.9% (n=9)	58.3% (n=7)	65.8%(n=25)	57.7% (n=41)		
Married	0% (n=0)	18.8% (n=3)	27.3% (n=9)	33.3% (n=7)	16.7% (n =2)	7.9% (n=3)	16.9% (n=12)		
Single	4.5% (n=1)	12.5% (n=2)	15.2% (n=5)	14.3% (n=3)	16.7% (n=2)	7.9%(n=3)	11.3% (n=8)		
Divorced	8.3% (n=3)	18.8% (n= 3)	6.1% (n=2)	4.8% (n=1)	8.3% (n=1)	15.8% (n=6)	11.3% (n=8)		
Other	4.5% (n=1)	0 % (n=0)	3.0% (n=1)	4.8% (n=1)	0% (n=0)	2.6%(n=1)	2.8% (n=2)		
Time living in facility (years)	3.0 (3.1); Median: 3.0	4.0 (3.1); Median: 3.5	7.3 (.2); Median: 7.0	9.5 (6.4); Median: 10.8	2.5 (2.2); Median: 2.5	3.1 (2.8); Median: 2.3	5.0 (5.1); Median: 3.3	<0.0001	<0.0001

Note. * can reflect higher than 100% due to mixed ethinicities:
Chi-Square tests used for categorical variables; independent t-tests used for continuous

Table A 2. *Differences (p-value) For Each Item and Sums For Baseline PCD Questionnaire*

	Differences (*p-values*)	
	Group	Site
Primary Movements: (sum)	0.24	0.59
1. Stoop, crouch, or kneel	0.94	0.37
2. Lift and carry 10lbs. (~a gallon of milk)	0.1	0.07
3. Go up and down 10 steps	0.094	0.22
4. Grasp or Handle (e.g. pick up a dime from a table)	0.38	0.22
5. Walking a 1/2 mile	0.31	0.34
ADLs (sum)	0.39	0.24
1. Bathing	0.81	0.54
2. Dressing	0.66	0.21
3. Getting in and out of bed	0.81	0.26
iADLs (sum)	0.35	0.52
1. Meal prep	0.18	0.56
2. Light housework (e.g. dishes)	0.34	0.72
3. Heavy housework (e.g. vacuum)	0.46	0.68
4. Managing Medications	0.23	0.22
Total (sum)	0.5	0.39

Note. PCD = Pre-Clinical Disability; ADL = Activities of Daily Living;
iADL = instrumental ADL;
Chi-Square tests used for categorical variables; independent t-tests used for continuous.

Table A 3. *Modification or Inability to Complete Tasks at Midpoint*

	Modification						Difficulty					
Task:	**STS (N=32)**		**SL (N=28)**		**Total (N=60)**		**STS (N=32**		**SL (N=28)**		**Total (N=60)**	
Primary Movements:	N	%	N	%	N	%	N	%	N	%	N	%
1. Stoop, crouch, or kneel	14	0.44	16	0.57	30	0.50	12	0.38	10	0.36	22	0.37
2. Lift and carry 10lbs. (~a gallon of milk)	11	0.34	6	0.21	17	0.28	2	0.06	7	0.25	9	0.15
3. Go up and down 10 steps	19	0.59	8	0.29	27	0.45	4	0.13	11	0.39	15	0.25
4. Grasp or Handle (e.g. pick up a dime from a table)	5	0.16	3	0.11	8	0.13	2	0.06	0	0.00	2	0.03
5. walking a 1/2 mile	19	0.59	13	0.46	32	0.53	3	0.09	6	0.21	9	0.15
ADLs	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
1. Bathing	8	0.25	7	0.25	15	0.25	1	0.03	2	0.07	3	0.05
2. Dressing	5	0.16	5	0.18	10	0.17	0	0.00	0	0.00	0	0.00
3. Getting in and out of bed	3	0.09	6	0.21	9	0.15	1	0.03	0	0.00	1	0.02
iADLs	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
1. Meal prep	24	0.75	18	0.64	42	0.70	3	0.09	4	0.14	7	0.12
2. Light housework (e.g. dishes)	10	0.31	12	0.43	22	0.37	0	0.00	0	0.00	0	0.00
3. Heavy housework (e.g. vacuum)	26	0.81	16	0.57	42	0.70	5	0.16	12	0.43	17	0.28
4. Managing Medications	2	0.06	6	0.21	8	0.13	1	0.03	0	0.00	1	0.02

Note. STS = Sit-To-Stand; SL = Sit Less; ADL = Activity of Daily Living; iADL = instrumental Activity of Daily Living

Table A 4. *Sum of Primary Movements, ADLs, and iADLs at Mid-intervention*

	STS	SL	Total
	Mean (SD)	Mean (SD)	Mean (SD)
Primary Movement Sum	2.9(1.4)	2.8(1.4)	2.9(1.4)
ADL Sum	.56(.91)	.71(1.05)	.63(.97)
iADL sum	2.2(.83)	2.4(.96)	2.3(.89)
Total	5.7(2.2)	6(2.5)	5.8(2.3)

Note. Reference Table A3 for individual items
SD = Standard Deviation; ADL = Activities of Daily Living;
iADL = instrumental ADL

Table A 5. *Modification or Inability to Complete Tasks at Post-Study*

	Difficulty						Modification					
Task:	**STS (N=30)**		**SL (N=28)**		**Total (N=58)**		**STS (N=30)**		**SL (N=28)**		**Total (N=58)**	
Primary Movements:	N	%	N	%	N	%	N	%	N	%	N	%
1. Stoop, crouch, or kneel	16	0.50	15	0.54	31	0.52	7	0.22	10	0.36	17	0.28
2. Lift and carry 10lbs. (~a gallon of milk)	3	0.09	4	0.14	7	0.12	2	0.06	5	0.18	7	0.12
3. Go up and down 10 steps	18	0.56	5	0.18	23	0.38	3	0.09	11	0.39	14	0.23
4. Grasp or Handle (e.g. pick up a dime from a table)	4	0.13	5	0.18	9	0.15	3	0.09	0	0.00	3	0.05
5. Walking a 1/2 mile	7	0.22	13	0.46	20	0.33	5	0.16	7	0.25	12	0.20
ADLs	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
1. Bathing	5	0.16	5	0.18	10	0.17	1	0.03	0	0.00	1	0.02
2. Dressing	2	0.06	4	0.14	6	0.10	0	0.00	0	0.00	0	0.00
3. Getting in and out of bed	4	0.13	7	0.25	11	0.18	0	0.00	0	0.00	0	0.00
iADLs	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
1. Meal prep	22	0.69	18	0.64	40	0.67	3	0.09	1	0.04	4	0.07
2. Light housework (e.g. dishes)	9	0.28	8	0.29	17	0.28	2	0.06	0	0.00	2	0.03
3. Heavy housework (e.g. vacuum)	19	0.59	13	0.46	32	0.53	9	0.28	13	0.46	22	0.37
4. Managing Medications	3	0.09	4	0.14	7	0.12	0	0.00	0	0.00	0	0.00

Note. STS = Sit-To-Stand; SL = Sit Less; ADL = Activity of Daily Living; iADL = instrumental Activity of Daily Living

Table A 6. *Sum of Primary Movements, ADLs, and iADLs at Post-intervention*

Task	STS Mean (SD)	SL Mean (SD)	Total Mean (SD)
Primary Movement Sum	2.3 (1.3)	2.7 (1.3)	2.5 (1.3)
ADL Sum	0.4 (.77)	0.57 (.997)	0.48 (.88)
iADL sum	2.3 (.94)	2.1 (1.2)	2.2 (1.1)
Total	4.9(2.1)	5.3 (2.6)	5.1 (2.4)

Note. Reference Table A5 for individual items
SD = Standard Deviation; ADL = Activities of Daily Living;
iADL = instrumental ADL

Table A 7. *Percent (%) and Number (n) of Valid Days of Participants at Baseline*

Valid Days	% (n)
5	5.6% (n=4*)
6	5.6 (n=4*)
7	88.7 (N=63)
Valid Percent	
71%	4.2% (n=3)
86%	2.8% (n=2)
100%	93% (N=66*)

Note. Valid Day is >10 hrs of awake time
*2 particpants could only wear a max of 6 days and 1 participant could only wear a max of 5 days (in all 3 cases they achieved 100% of valid days)

Table A 8. *Percent of Participants to Fill out Sleep Logs*

Sleep Log	% (n)
Complete (>75%)	75% (n=53)
Partially Complete (25-50%)	4%(n=3)
Incomplete (<25%)	21%(n=15)

Note.

Table A 9 *Adverse Events by Site*

	STS		Sit Less		Total
Category of AE	**STS-A**	**STS-B**	**SL-A**	**SL-B**	
Serious	4	3	3	1	11
Not-serious	5	1	10	2	18
Total:	**9**	**4**	**13**	**3**	**29**
Discontinued due to AE	3	1	1	0	5
Not Serious AE's					
Falls (uninjured)	2	1	4	0	7
Sickness (e.g., cold)	0	0	2	0	2
Joint/muscle pain	2	0	2	1	5
Skin irritation	1	0	2	1	4
Serious AE's					
Fall (hospitalization)	1	2	2	1	6
TIA			1		1
Surgery	2				2
Chest pain	1				1
Excessive edema in legs		1			1

Note. AE= Adverse Event; STS = Sit to stand; SL = Sit Less
Not-serious included: non-hospitalized sickness such as cold, sinus infection, knee pains, etc.

Appendix B

Stand Up Now (SUN): Health Coach Session and Scripts Overview

Health coaching sessions are designed to target behavior change techniques (BCTs) from Social Cognitive Theory. The specific BCTs have also been used in previous individual level SB interventions in older adults and multi-level physical activity interventions, including the in the Continuing Care Retirement Community (CCRC) setting (Gardiner et al., 2011; Hankonen et al., 2016; Kerr et al., 2012; Kerr et al., 2015; Rosenberg et al., 2016). Specific BCTs and how SUN will target each BCT are described in **Table 1.** Individual sessions will be led by a health coach trained in motivational interviewing, the specific SUN health coach scripts, and working with older adults. Training will involve role-playing and practice with real scenarios from previous pilot health coaching sessions. Health coach scripts have been modified from previously effective interventions, with specific messages targeted at the intervention group's goal (increase STS transitions or decrease sitting time throughout the day) (Kerr et al., 2016; Rosenberg et al., 2015). Over the 12 weeks, sessions will decrease in contact time and will transition from in-person sessions (~60 minutes) to phone call check-ins (~10 minutes). The first health coaching sessions (weeks 1 & 2) will last approximately 60 minutes. During this first week, the participants will be asked to rewear the activPAL in order to give immediate feedback the following week at their health coach session. After these first two sessions, the participant will no longer wear the activPAL until mid-point (week 6) and post (week 12) measures. Subsequent health coach sessions will decrease in length (i.e., 40 minutes for weeks 3, 6, 7) and the last session (week 12) will be a brief in-person check-in and distribution of the measurement device, lasting about 20 minutes. Phone call check-ins will begin at about 20 minutes (weeks 4, 5) and will decrease to about 10 minutes (weeks 8-11) 9. These sessions are summarized in the table below.

Week	Health Coach Session	ACTIVPAL (AP)/MEASURES
1	#1. In-Person~60min.	Review AP from Baseline GIVE ACTIVPAL TO WEAR AGAIN
2	#2. In-Person~60min	Review AP from week 1
3	#3. In-Person~40min	
4	#4Phone~20min	
5	#5.Phone~20min	
6	#6. In-Person~40min	GIVE ACTIVPAL TO WEAR
7	#7. In-Person~40min	Review AP from week 6 MIDPOINT MEASURES
8	#8. Phone~10min	
9	#9. Phone~10min	
10	#10. Phone~10min	
11	#11. Phone~10min	
12	#12. In-Person~20min	GIVE ACTIVPAL TO WEAR
13	FINAL STUDY VISIT In-Person~20min	Give AP graph from week 12 POST MEASURES

Table 1: *Targeted Behavior Change Techniques (BCT)*	
BCTs*	**SUN component**
Goal setting	Goals set in counseling sessions to increase STS
Graded tasks	Incremental goals of STS each week
Rewards/Incentives	Certificates/Rewards when goals are achieved
Self-monitoring	Tracking sheet
Plan/Implementation	Counseling session discussions and brainstorming
Prompts	Signage, bookmarks, magnets
Information about behavior outcome	Discussions and education on health affects of SB; Brochure/information in handouts
Feedback	Graphical feedback from ActivPAL

In – Person Coaching Sessions: Weeks* 1, 2, 3, 6, 7, 12

*Week indicates the start of that week

In addition to specific behavior change technique discussions and activities, each health coach session will consist of four components:

1. Personal activPAL Feedback (for sessions 1, 2, 7 & at the end of week 12)
2. Goal Setting
3. Action Plan to complete goals
4. Confidence Level to complete goals

I. Personal ActivPAL Feedback (for sessions 1 & 2, 7)

After the activPAL is worn, we will generate graphs to tangibly show participants either their sit-to-stand transitions or total sitting time, broken down by day and hours in the day. This individualized feedback will be used to discuss strategies to target their sedentary behavior change goal throughout the week and set goals for the following week.

II-III. Goal Setting and Action Plan

Based on their activPAL feedback, the health coach will guide the participant to set goals and create an action plan as to how, when, and where they will achieve those goals. Depending on SUN group (either STS group or reduce sitting group), we will encourage participants to increase a total of 30 STS/day or 60 minutes/day over the 12 weeks. We will start with increasing by 10 STS/day or 10 minutes/day at the first week and then increase by 5 STS/day or 10 minutes per day for the remainder weeks until they reach an additional 30 STS/day or 60 minutes per day. We will then encourage them to maintain that level or, if appropriate, we will encourage them to continue to increase.

Week 1: 10 STS/10 minutes per day
Week 2: 15/20 minutes per day
Week 3: 20/30 minutes per day
Week 4: 25/40 minutes per day
Week 5: 30/50 minutes per day
Week 6-12: 30/60 minutes per day

Although we have set a study goal of an increase of 30 STS/day or 60 minutes/day by the end of the study. Health coaches are trained to help modify goals to each individual if goals are needed to be scaled up or

down. The action plan will also include discussion of foreseeable barriers and how to come up with solutions to those barriers.

IV. Importance & Confidence:

At the end of each health coaching session, participants will be asked two questions:

1. On a scale of 1 to 10, how important is this goal for you?
2. On a scale of 1 to 10, how confident are you that you can accomplish this goal this week?

If the participant rates either of these values as <7, then the health coach will re-discuss the goals and plan with the participant and modify if appropriate.

Phone Call Health Coach Sessions:

The purpose of the phone call coaching sessions is to check-in with the participant about their goals and discuss any challenges the participant is experiencing. We anticipate phone calls will be about 20 minutes for weeks 4 & 5 and then about 10 minutes for weeks 8-11. The phone calls will consist of:

I. Check-in/Rapport
II. Reflections on current goal
    a. Current Challenges and Successful strategies
III. New goal setting
IV. Confidence and Importance Rating

I. Check-in/Rapport

Health coaches will continue to establish rapport at the beginning of each call.

II. Reflections on current goal

Next, the participant will discuss their experience with the current goals. Open-ended and probing questions will be used to discuss current challenges and successes to changing their sedentary behavior during their day.

III. New goal setting :

Next the health coach will then guide the participant to set a new goal for the week or continue to maintain their current goal.

IV. Confidence and Importance Rating:

Similar to in-person sessions, the participant will be asked on a scale of 1-10, how important their goal is and how confident they are to achieve that goal.

The health coach will close with asking if they have any questions and reminding them of their schedule for the following week session (either in-person or phone call, depending on the week).

***Note. Questions asking about adverse events will always be asked first and document. If the participant indicates they experienced an adverse event we will follow up with questions about if the event was related/unrelated to the study and if it was serious. A protocol for the IRB reporting is outlined in the IRB documentation.*

Example of Health Coach Record Sheet (Week 2)

Visit 2: Date_____ Health Coach Initials: _____ Participant ID_____

Start Time:_____

1. Any Adverse Events? (circle)

Yes (related to study) Yes (unrelated to study) No

If Yes, please circle one and comment: Serious Not Serious

2. ActivPAL feedback comments (if applicable): (irritation, problems, complaints, etc)

3. Willing to wear another week (they won't until week 6)? Yes No

If No, Why:

4. Achieved Goal of last week? Yes No

Comments:

5. Goal of _____ STS/min less sitting minutes for this week?
6. Importance (1-10) _____
7. Confidence (1-10)_____

Other comments from today:

End Time: _____

Example of recruitment flyer

PARTICIPATE IN RESEARCH ON AGING AT [redacted]

The purpose of this study is to engage with older adults that no longer feel in their top physical condition to help stand up more to maintain their health and independence.

What will participation involve?

- 12 weekly meetings with a health coach (in-person & phone call).
- Measurements (survey and brief physical assessment) at the beginning, middle (6 weeks), and end (12 weeks) of the study.

What are the benefits?

- Help add to the research on aging to better understand how movement throughout the day will help maintain independence and quality of life.
- Weekly health coaching sessions, free materials and information to help improve function, and personal feedback on physical movement pattern and assessments related to your health.

Am I eligible? Contact the research team for an eligibility screening. Some criteria include:

- Over 60 years old
- Not diagnosed with dementia
- Can stand and walk 10 feet without a wheelchair (canes/walkers OK)
- Do not currently attend more than 1 exercise class per week

If interested, call to set up a screening visit:

Katie Thralls

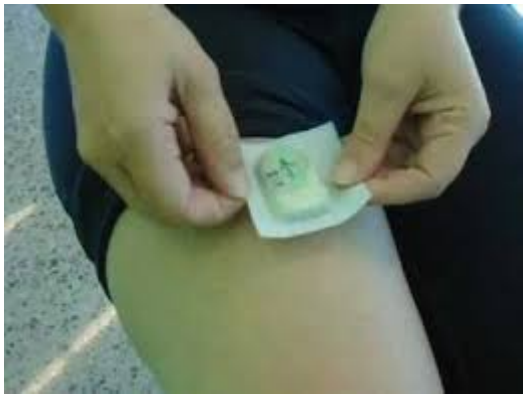
[redacted]

Wearing the activPAL Description Flyer

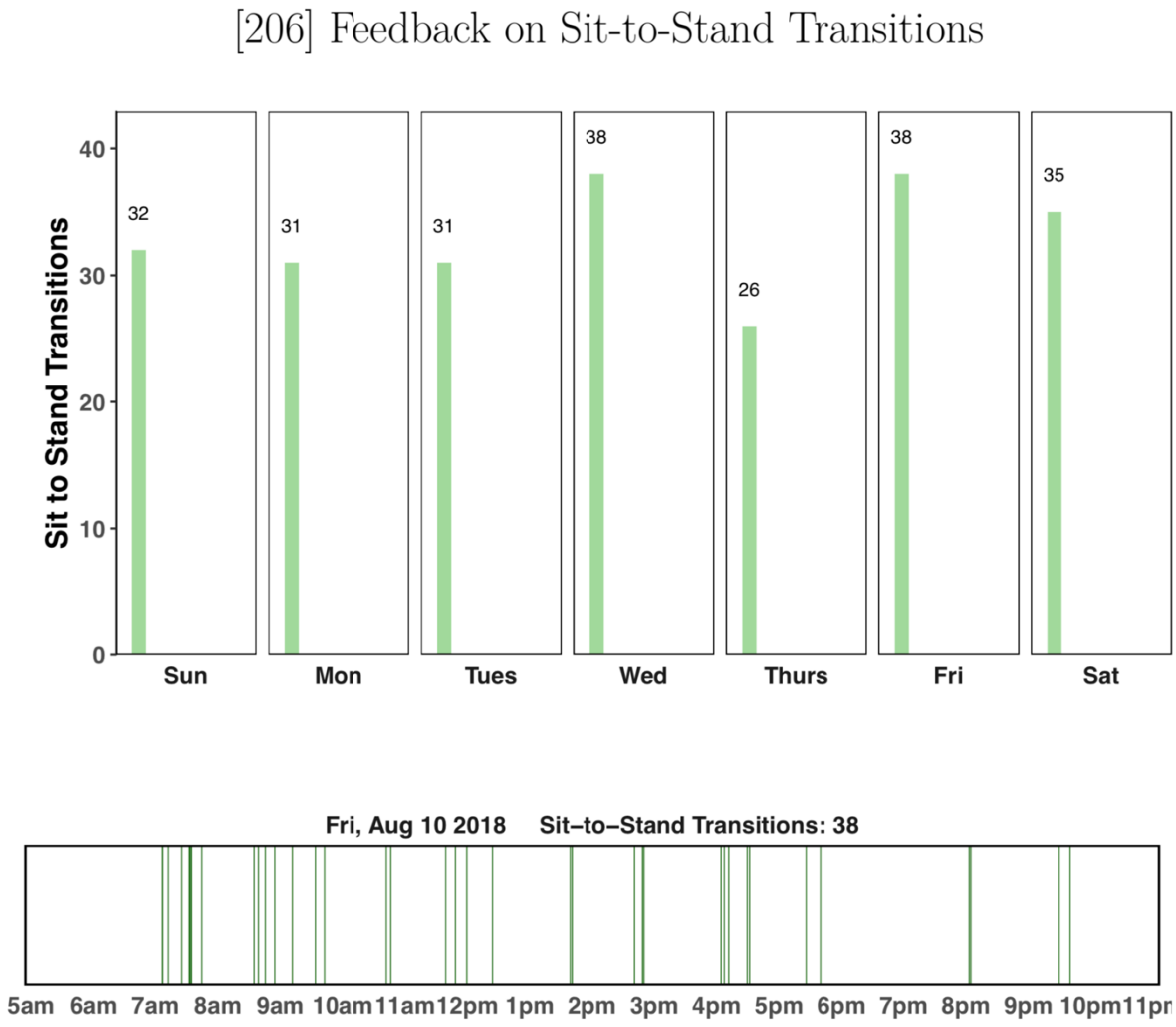
Wearing the activPAL

- **MOST IMPORTANT:** Write down when you go to bed and wake up on the paper log.
- The goal of this week is to have you wear this device and go about your usual lifestyle. Keep your normal schedule and routine.
- Do not remove the device. It is waterproof and can stay on at all times.
- Questions: Call [redacted]
- We will come back and pick it up before your next session!

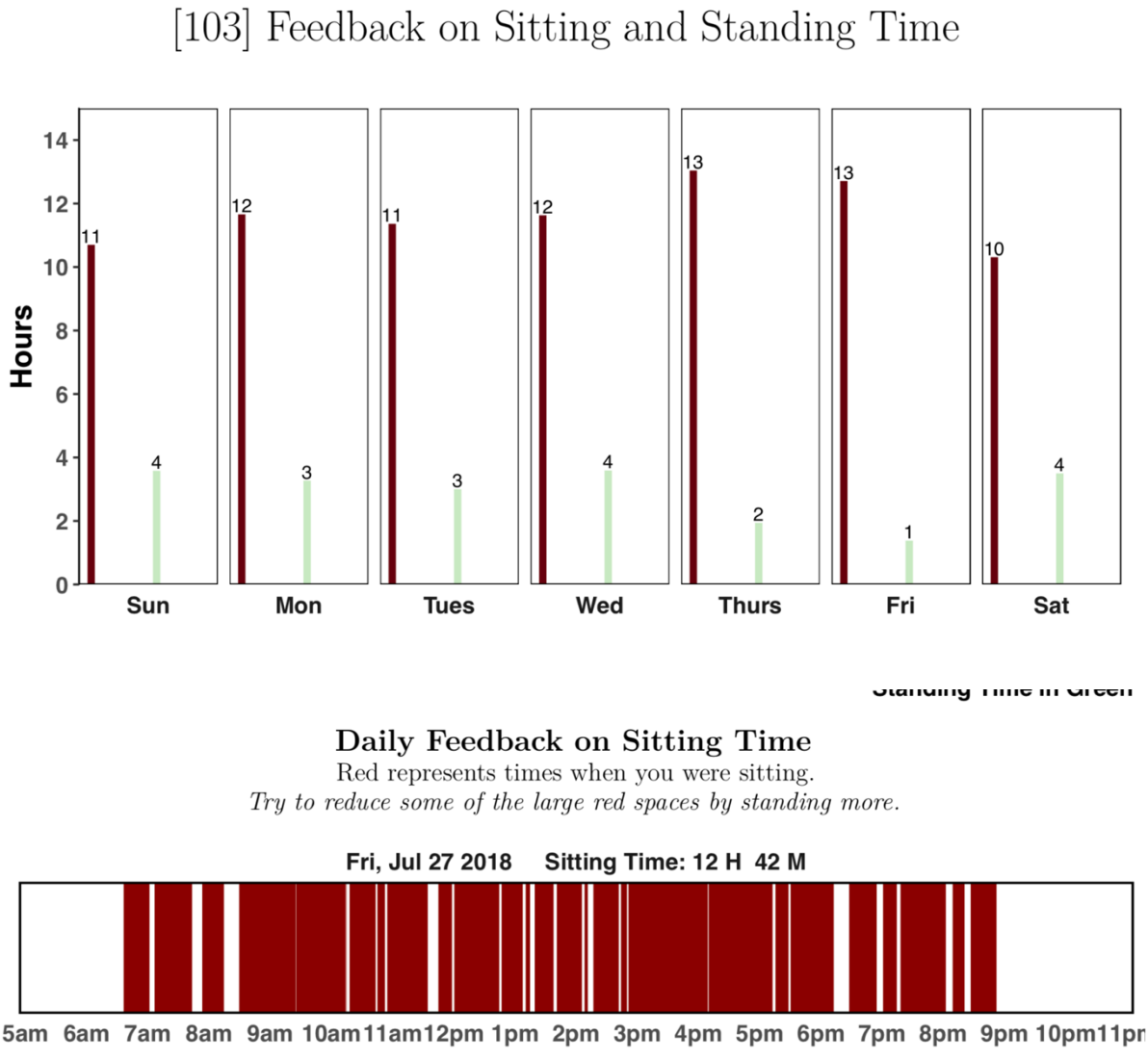
_____



Example of activPAL graph feedback for SUN^{STS}



Example of activPAL graph feedback for SUN[SL]



Appendix C

Pre-Clinical Disability Questionnaire

Next we are going to ask you about your ability and the way you complete various tasks. For each task listed you will answer one of three following options:

1. No difficulty in completion.
2. Modification in how you complete either by frequency (reduce/avoid completion) or mode (change the way you complete) *because of a health or physical problem.*
3. Much difficulty: inability to complete or need assistance *because of a health or physical problem.*

Task:	**Level of Difficulty (Circle 1)**		
Primary Movements:			
1. Stoop, crouch, or kneel	No Difficulty	Modification	Difficulty
2. Lift and carry 10lbs. (~a gallon of milk)	No Difficulty	Modification	Difficulty
3. Go up and down 10 steps	No Difficulty	Modification	Difficulty
4. Grasp or Handle (e.g. pick up a dime from a table)	No Difficulty	Modification	Difficulty
5. walking a 1/2 mile	No Difficulty	Modification	Difficulty
ADLs			
1. Bathing	No Difficulty	Modification	Difficulty
2. Dressing	No Difficulty	Modification	Difficulty
3. Getting in and out of bed	No Difficulty	Modification	Difficulty
iADLs			
1. Meal prep	No Difficulty	Modification	Difficulty
2. Light housework (e.g. dishes)	No Difficulty	Modification	Difficulty
3. Heavy housework (e.g. vacuum)	No Difficulty	Modification	Difficulty
4. Managing Medications	No Difficulty	Modification	Difficulty

Short Physical Performance Battery Instructions and Score Sheet

Short Physical Performance Battery Protocol and Score Sheet

Participant ID

_____Date: _____ Tester Initials:_____

All of the tests should be performed in the same order as they are presented in this protocol. Instructions to the participants are shown in bold italic and should be given exactly as they are written in this script.

1. BALANCE TESTS

The participant must be able to stand unassisted without the use of a cane or walker. You may help the participant to get up.

Now let's begin the evaluation. I would now like you to try to move your body in different movements. I will first describe and show each movement to you. Then I'd like you to try todo it. If you do not feel safe, tell me and we'll move on to the next one. Let me emphasize that I do not want you to try to do any exercise that you feel might be unsafe.

Do you have any questions before we begin?

A. Side-by-Side Stand

1. ***Now I will show you the first movement.***
2. (Demonstrate) ***I want you to try to stand with your feet together, side-by-side, for about 10 seconds.***
3. ***You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.***
4. Stand next to the participant to help him/her into the side-by-side position.
5. Supply just enough support to the participant's arm to prevent loss of balance.
6. When the participant has his/her feet together, ask ***"Are you ready?"***
7. Then let go and begin timing as you say, ***"Ready, begin."***
8. Stop the stopwatch and say **"*Stop*"** after 10 seconds or when the participant steps out of position or grabs your arm.
9. If participant is unable to hold the position for 10 seconds, record result and go to the gait speed test.

B. Semi-Tandem Stand

1. ***Now I will show you the second movement.***
2. (Demonstrate) ***Now I want you to try to stand with the side of the heel of one foot touching the big toe of the other foot for about 10 seconds. You may put either foot in front, whichever is more comfortable for you.***
3. ***You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.***
4. Stand next to the participant to help him/her into the semi-tandem position
5. Supply just enough support to the participant's arm to prevent loss of balance.
6. When the participant has his/her feet together, ask ***"Are you ready?"***
7. Then let go and begin timing as you say ***"Ready, begin."***
8. Stop the stopwatch and say ***"Stop"*** after 10 seconds or when the participant steps out of position or grabs your arm.
9. If participant is unable to hold the position for 10 seconds, record result and go to the gait speed test.

C. Tandem Stand

1. ***Now I will show you the third movement.***
2. (Demonstrate) ***Now I want you to try to stand with the heel of one foot in front of and touching the toes of the other foot for about 10 seconds. You may put either foot in front, whichever is more comfortable for you.***
3. ***You may use your arms, bend your knees, or move your body to maintain your balance, but try not to move your feet. Try to hold this position until I tell you to stop.***
4. Stand next to the participant to help him/her into the tandem position.
5. Supply just enough support to the participant's arm to prevent loss of balance.
6. When the participant has his/her feet together, ask ***"Are you ready?"***
7. Then let go and begin timing as you say, ***"Ready, begin."***
8. Stop the stopwatch and say ***"Stop"*** after 10 seconds or when the participant steps out of position or grabs your arm.

SCORING:

A. Side-by-Side stand

Held for 10 sec ❒1 point
Not held for 10 sec ❒0 points
Not attempted ❒0 points

If 0 points, end Balance Tests

Number of seconds held if less than 10 sec: _._ _ Sec

If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not hold position unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (specify)	6
Participant refused	7

B. Semi-Tandem Stand

Held for 10 sec ❒1 point
Not held for 10 sec ❒0 points
Not attempted ❒0 points

(circle reason to the right)

If 0 points, end Balance Tests

Number of seconds held if less than 10 sec:

____._ Sec

Circle which foot is in front:
R **L**

If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not hold position unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (specify)	6
Participant refused	7

C. Tandem Stand

Held for 10 sec ❒2 point
Held for 3 to 9.99 sec ❒1 points
Held for < than 3 sec ❒0 points
Not attempted ❒0 points

(circle reason above)

Number of seconds held if less than 10 sec:

____.___Sec

Circle which foot is in front:
R **L**

If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not hold position unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (specify)	6
Participant refused	7

D. Total Balance Tests score _ (sum points)

Comments:_____

_____

2. GAIT SPEED TEST

Now I am going to observe how you normally walk. If you use a cane or other walking aid and you feel you need it to walk a short distance, then you may use it.

A. First Gait Speed Test

1. ***This is our walking course. I want you to walk to the other end of the course at your usual speed, just as if you were walking down the street to go to the store.***
2. Demonstrate the walk for the participant.
3. ***Walk all the way past the other end of the tape before you stop. I will walk with you. Do you feel this would be safe?***
4. Have the participant stand with both feet touching the starting line.
5. ***When I want you to start, I will say: "Ready, begin."*** When the participant acknowledges this instruction say: ***"Ready, begin."***
6. Press the start/stop button to start the stopwatch as the participant begins walking.
7. Walk behind and to the side of the participant.
8. Stop timing when one of the participant's feet is completely across the end line.

B. Second Gait Speed Test

1. ***Now I want you to repeat the walk. Remember to walk at your usual pace, and go all the way past the other end of the course.***
2. Have the participant stand with both feet touching the starting line.
3. ***When I want you to start, I will say: "Ready, begin."*** When the participant acknowledges this instruction say: "Ready, begin."
4. Press the start/stop button to start the stopwatch as the participant begins walking.
5. Walk behind and to the side of the participant.
6. Stop timing when one of the participant's feet is completely across the end line.

GAIT SPEED TEST SCORING:

Length of walk test course: 4 meters ❒ (13 feet 1.5inches)

A. Time for First Gait Speed Test (sec)

1. Time for 3 or 4 meters_____._ sec

2. If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not walk unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (Specify)_____	6
Participant refused	7
Complete score sheet and go to chair stand test	

3. Aids for first walk..... None ❒ Cane ❒ Other ❒

Comments:_____

_____

_____

B. Time for Second Gait Speed Test (sec)

1. Time for 3 or 4 meters_____._ sec

2. If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not walk unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (Specify)	6
Participant refused	7

3. Aids for second walk..... None ❒ Cane ❒ Other ❒

What is the time for the faster of the two walks?

Record the shorter of the two times_____._ sec

[If only 1 walk done, record that time]_____._ sec

If the participant was unable to do the walk: ❒0 points

For 4-Meter Walk:

If time is more than 8.70 sec:	❒1 point
If time is 6.21 to 8.70 sec:	❒2 points
If time is 4.82 to 6.20 sec:	❒3 points
If time is less than 4.82 sec:	❒4 points

3. CHAIR STAND TEST

Single Chair Stand

1. ***Let's do the last movement test. Do you think it would be safe for you to try to stand up from a chair without using your arms?***
2. ***The next test measures the strength in your legs.***
3. (Demonstrate and explain the procedure.) ***First, fold your arms across your chest and sit so that your feet are on the floor; then stand up keeping your arms folded across your chest.***
4. Please stand up keeping your arms folded across your chest. (Record result).
5. If participant cannot rise without using arms, say "Okay, try to stand up using your arms." This is the end of their test. Record result and go to the scoring page.

Repeated Chair Stands

1. ***Do you think it would be safe for you to try to stand up from a chair five times without using your arms?***
2. (Demonstrate and explain the procedure): ***Please stand up straight as QUICKLY as you can five times, without stopping in between. After standing up each time, sit down and then stand up again. Keep your arms folded across your chest. I'll be timing you with a stopwatch.***
3. When the participant is properly seated, say: ***"Ready? Stand"*** and begin timing.
4. Count out loud as the participant arises each time, up to five times.
5. Stop if participant becomes tired or short of breath during repeated chair stands.
6. Stop the stopwatch when he/she has straightened up completely for the fifth time.
7. Also stop:
    - If participant uses his/her arms
    - After 1 minute, if participant has not completed rises
    - At your discretion, if concerned for participant's safety
8. If the participant stops and appears to be fatigued before completing the five stands, confirm this by asking ***"Can you continue?"***
9. If participant says "Yes," continue timing. If participant says "No," stop and reset the stopwatch.

SCORING

Single Chair Stand Test

	Yes	No	
A. Safe to stand without help	❒	❒	
B. Results:			
Participant stood without using arms	❒		→ Go to Repeated Chair Stand Test
Participant used arms to stand	❒		→ End test; score as 0 points
Test not completed	❒		→ End test; score as 0 points

C. If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not stand unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (Specify)	6
Participant refused	7

Repeated Chair Stand Test

	Yes	No
A. Safe to stand five times	❒	❒

B. If five stands done successfully, record time in seconds.
Time to complete five stands_____._ sec

C. If participant did not attempt test or failed, circle why:

Tried but unable	1
Participant could not stand unassisted	2
Not attempted, you felt unsafe	3
Not attempted, participant felt unsafe	4
Participant unable to understand instructions	5
Other (Specify)	6
Participant refused	7

Scoring the Repeated Chair Test

Participant unable to complete 5 chair stands or completes stands in >60 sec:	❒0 points
If chair stand time is 16.70 sec or more:	❒1 points
If chair stand time is 13.70 to 16.69 sec or more:	❒2 points
If chair stand time is 11.20 to 13.69 sec:	❒3 points
If chair stand time is 11.19 sec or less:	❒4 points

Scoring for Complete Short Physical Performance Battery

Test Scores

Total Balance Test score_____points

Gait Speed Test score_____points

Chair Stand Test score_____points

Total Score _____**points** (sum of points above)

EXTRA COMMENTS BELOW:

Demographics Questions

Please tell us the racial or ethnic group(s) with which you most closely identify. **[SELECT ALL THAT APPLY]**

- ☐ Latina/o
- ☐ Hispanic
- ☐ Native American
- ☐ Alaskan Native
- ☐ Native Hawaiian/Pacific Islander
- ☐ Black/African American
- ☐ East Asian (Vietnamese, Korean, Chinese, Japanese, etc.)
- ☐ White/Caucasian/Anglo/European American
- ☐ South Asian (India, Pakistan, etc.)
- ☐ Other, please tell us: _____
- ☐ I do not want to answer this question

When were you born? _____/_____/_____(M/D/Y)

What is your gender? _____ Female _____ Male

What is your current marital status? **[SELECT ONE]**

- ☐ Single
- ☐ Married
- ☐ Divorced
- ☐ Other, please tell us:
- ☐ I do not want to answer this question
- ☐ Widowed
- ☐ Common Law
- ☐ Domestic Partner
- ☐ Separated

What is your highest level of education **completed**? **[SELECT ONE]**

- ☐ Less than 8th Grade
- ☐ Junior High/Secondary School (9th Grade)
- ☐ Some High School (10th or 11th Grade)
- ☐ Completed High School (or GED)
- ☐ Other, please tell us:
- ☐ I do not want to answer this question
- ☐ Some College or Vocational Training
- ☐ Completed Bachelor Degree
- ☐ Some Graduate Training
- ☐ Completed Graduate Degree

Depression Survey: CES-D

Instructions:
Below is a lift of some of the ways you may have felt or behaved. Please indicate how often you felt this way during the ***past week*** by checking the appropriate box for each question.

	Rarely or none of the time (less than 1 day)	**Some or a little of the time** (1-2 days)	**Occasionally or a moderate amount of time** (3-4 days)	**All of the time** (5-7
1. I was bothered by things that usually don't bother me.	☐	☐	☐	☐
2. I had trouble keeping my mind on what I was	☐	☐	☐	☐
3. I felt depressed.	☐	☐	☐	☐
4. I felt that everything I did was	☐	☐	☐	☐
5. I felt hopeful about the future.	☐	☐	☐	☐
6. I felt fearful.	☐	☐	☐	☐
7. My sleep was restless.	☐	☐	☐	☐
8. I was happy.	☐	☐	☐	☐
9. I felt lonely.	☐	☐	☐	☐
10. I could not "get going."	☐	☐	☐	☐

ACTIVPAL SLEEP/WAKE JOURNAL

PARTICPANT ID _____

	WAKE	SLEEP	WAKE	SLEEP	OTHER COMMENTS: (Changed adhesive or extra nap)
Day 1 _____	X				
Day 2 _____					
Day 3 _____					
Day 4 _____					
Day 5 _____					
Day 6 _____					
Day 7 _____					
Day 8 _____					

ActivPAL Satisfaction Survey

1. On a scale of 1 to 5 how bothered were you by the activPAL device?

1	2	3	4	5
Not bothered				Very bothered

2. How often did you change the device over the last 7 days?

0	1	2	3	4+

3. How often did you need outside help from a staff member or another person with something, due to wearing the device?

0	1	2	3	4+

4. Would you be willing to wear the device for another week?

Yes No

5. Please describe any other overall comments related to your experience with wearing the activPAL device:

SUN Satisfaction Survey

How satisfied are you with the following Stand Up Now (SUN) program components:

1. In-person health coaching sessions:

a. Length of sessions

1	2	3	4	5
Not Satisfied				Very Satisfied

b. Discussion content of sessions

1	2	3	4	5
Not Satisfied				Very Satisfied

c. Graphical feedback from activPAL device

1	2	3	4	5
Not Satisfied				Very Satisfied

d. Other materials (e.g., self -monitoring sheet, worksheets)

1	2	3	4	5
Not Satisfied				Very Satisfied

e. number of health coach sessions

1	2	3	4	5
Not Satisfied				Very Satisfied

2. Phone Call health coaching seesions:

a. Length of phone call

1	2	3	4	5
Not Satisfied				Very Satisfied

b. Content of phone calls sessions

1	2	3	4	5
Not Satisfied				Very Satisfied

c. Number of phone calls sessions

1	2	3	4	5
Not Satisfied				Very Satisfied

Other comments:

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