Sedentary Behavior and Physical Activity of Older Adults

by

Katelyn E. Webster

A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Nursing)
in the University of Michigan
2021

Doctoral Committee:

Professor Janet Larson, Chair
Professor Natalie Colabianchi
Associate Professor Neha Gothe, University of Illinois at Urbana-Champaign
Research Professor Robert Ploutz-Snyder
Professor Julia Seng
Professor Ellen Lavoie Smith, University of Alabama at Birmingham

Katelyn E. Webster

katewebs@umich.edu

ORCID iD: 0000-0002-8443-3115

DEDICATION

This work is dedicated to my grandfather, Hugh Campbell, who was a huge supporter of my educational endeavors. It is also dedicated to my parents, John and JoLynn Webster, my brother Ethan, and my fiancé Benjamin who have given me endless love and encouragement. Thanks be to God.

ACKNOWLEDGEMENTS

I would like to sincerely thank my mentor Dr. Janet Larson for her guidance and encouragement over the past four years. Thank you to my committee members Drs. Natalie Colabianchi, Neha Gothe, Robert Ploutz-Snyder, Julia Seng, and Ellen Smith for generously sharing their expertise. Thank you to Dr. Nancy (Amby) Gallagher and Weijiao Zhou for assisting with reviewing abstracts and articles for the Paper 1 systematic review. Thank you to Dr. Gallagher for also auditing interviews for the Paper 3 qualitative study. Thank you to Kate Saylor for providing support as a health sciences informationist for the systematic review. Thank you to Dr. Ron Dechert for assisting with ActivPAL data trimming for the Paper 2 measurement study.

I would like to acknowledge my funding sources, NIH NINR grant T32NR016914 (Complexity: Innovations in Promoting Health and Safety) and NIH NINR grant F31NR018784. I also received support from the University of Michigan School of Nursing New Investigator Award. The parent study for the Paper 2 secondary analysis was funded by NIH NINR grant R01NR016093.

My sincere gratitude goes to the assisted living residents who participated in my interview study and shared their experiences, as well as the facility administrators and staff who facilitated recruitment.

Thank you to my peers in the PhD program who have provided support along the way. Thank you to Boo and Cinnamon for their companionship during the writing process.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

High levels of sedentary behavior increase the risk for chronic disease, loss of physical function, disability, and all-cause mortality. Oldest old adults (age 80 and older) and older adults in assisted living are especially at risk for health decline and frailty. Accurate sedentary behavior measurement is critical in order to assess associated health risks and the effectiveness of interventions for reducing sedentary behavior. There is great need for interventions to reduce sedentary behavior and increase light physical activity in older adults in assisted living. This type of intervention could reduce health risks, slow functional decline and frailty, and delay residents' needs for higher-level care such as a nursing home. The aims of this dissertation are the following: 1) Characterize sedentary behavior in community-dwelling adults age 80 and older by conducting a systematic review and meta-analysis focused on volume of sedentary behavior and factors associated with sedentary behavior in this population; 2) Identify optimal methods for processing objectively measured sedentary behavior data by analyzing ActiGraph vertical axis and vector magnitude data with multiple combinations of filters, non-wear algorithm lengths, and cut-points and by comparing ActiGraph estimates to ActivPAL-measured sedentary time in inactive people with chronic obstructive pulmonary disease; 3) Gather feedback from assisted living residents on a proposed Active for Life in Assisted Living intervention by conducting one-on-one interviews. A secondary aim was to explore contextual factors that may influence how the intervention will be implemented with this population. For aim 1, twenty-one articles were included in the review and meta-analysis showed adults 80 years and older are sedentary for 10.6

hours during the waking day. Although few articles examined factors associated with sedentary behavior in this age group, older age, male gender, non-Hispanic white race/ethnicity, social disadvantage, and declining cognitive function (in men) were associated with increased sedentary time. For aim 2, a secondary data analysis was conducted with a sample of older adults with chronic obstructive pulmonary disease (n=59) who wore ActiGraph and ActivPAL devices for seven days. Thirty techniques for processing ActiGraph sedentary behavior data were compared to ActivPAL-measured sedentary behavior using the Bland-Altman method. The best ActiGraph technique was vector magnitude data with low frequency extension filter, 120-minute non-wear algorithm, and sedentary behavior cut-point of <40 counts/15 seconds (concordance correlation 0.839; mean difference -11.7 minutes/day). For aim 3, one-on-one semi-structured interviews were conducted with 20 assisted living residents. They were presented the proposed Active for Life intervention and asked questions to inform its development. Data were analyzed using content and thematic analysis. Assisted living residents recommended shorter intervention sessions, shorter overall intervention length, and framing the goal of the intervention as increasing light physical activity. The thematic analysis identified factors that could influence intervention implementation, including motivation, safety, beliefs about aging, varying abilities, social influences, and physical activity opportunities in AL. As a whole, the results of this dissertation contribute to our knowledge of sedentary behavior in older adults. Findings highlight the high volume of sedentary behavior in the oldest old, showing opportunity for intervention to reduce sedentary time. We also identified optimal methods for measuring sedentary behavior in older adults, which may guide data processing decisions. In addition, we gathered valuable feedback on a proposed intervention to reduce sedentary behavior of assisted living residents, an important first step in developing an intervention appropriate for this population.

CHAPTER I

Introduction

Sedentary behavior is defined as any waking behavior characterized by an energy expenditure ≤1.5 metabolic equivalents (METs) while in a sitting, reclining or lying posture (Tremblay et al., 2017) and is a major threat to public health (Leitzmann et al., 2018). This problem is increasingly prevalent because our modern Western society encourages a sedentary lifestyle through passive transportation, sedentary jobs, and communication technologies (Leitzmann et al., 2018). Increased sedentary behavior is associated with greater rates of chronic diseases, including cardiovascular disease, cancer, and type 2 diabetes, as well as all-cause mortality (Biswas et al., 2015; Leitzmann et al., 2018; Park et al., 2020). A 30-minute/day increase in sedentary behavior has been associated with a 15% increase in mortality risk (Jefferis et al., 2018). Physiologically, sedentary behavior causes metabolic dysfunction and may negatively impact bone mineral density (Tremblay et al., 2010).

Based on analyses that adjust for levels of physical activity, researchers have often described the health risks associated with sedentary behavior as being independent of physical activity, meaning that individuals may be at risk even if they are meeting physical activity guidelines but are highly sedentary the remaining hours of the day (Owen et al., 2010). However, there is evidence that the relationship between sedentary behavior and all-cause mortality varies when stratified by the amount of moderate-to-vigorous physical activity and that the risks associated with sedentary behavior may be attenuated by performing high levels of moderate-to vigorous physical activity ("2018 Physical Activity Guidelines Advisory Committee Scientific Report," 2018). It may be challenging for some populations such as older adults or those with chronic disease to perform recommended levels of moderate-to-vigorous physical activity (Gammack, 2017).

Sedentary behavior is especially relevant to the older adult population (typically defined as age ≥60 or ≥65), as this group has been identified as the most sedentary age group (Matthews et al., 2008) and individuals tend to become even more sedentary as they age (T. Chen et al., 2015; Evenson et al., 2014; Shiroma et al., 2013). Older adults also have a high prevalence of chronic conditions and these conditions are associated with higher levels of sedentary behavior (Bellettiere et al., 2019; Buttorff, 2017; Plotnikoff et al., 2015). High levels of sedentary behavior are associated with frailty, poor functional abilities, increased disability, and less successful aging in older adults (Dogra & Stathokostas, 2012). Only 10-15% of older adults meet activity guidelines of 150 minutes of moderate activity per week, but these guidelines are often unrealistic for older adults, especially those with multiple comorbid conditions or assisted living residents who tend to be older (52.6% are 85 years and older) with multiple comorbid conditions (Hyde et al., 2007; Sparling et al., 2015). The 2018 *Physical Activity Guidelines for Americans* recommends that older adults replace sedentary behavior with light physical activity, and substantial evidence suggests light physical activity improves cardiometabolic health and reduces mortality risk (Fuzeki et al., 2017; *Physical activity guidelines for Americans, 2nd edition*, 2018). Increasing light physical activity by 30-minutes/day may decrease mortality risk by 17% (Jefferis et al., 2018). Increasing light physical activity may be more attainable for many older adults than increasing moderate-to-vigorous physical activity (Sparling et al., 2015). Light physical activity includes activities such as standing, slow walking, and light house work.

The main population of interest of this dissertation was older adults who reside in assisted living. A literature review had recently been completed on factors influencing physical activity and physical activity interventions in assisted living (Vos, 2017). For that reason, this dissertation instead included a systematic review (Paper 1) focused on community-dwelling oldest-old adults, people who are a similar age as most assisted living residents. This will allow for future comparison between assisted living residents and those living in the community. Paper 2 involved a population of inactive community-dwelling older adults with chronic illness. Papers 1 and 2 are therefore designed to inform work with the assisted living population who tend to be older and have chronic health conditions. Paper 3 directly involved the assisted living population.

Paper 1 Statement of the Problem and Purpose

Published systematic literature reviews have focused on sedentary behavior prevalence and determinants in adults 60 or 65 years of age and older (Chastin et al., 2015; Harvey et al., 2013, 2015; Wullems et al., 2016). However, no literature reviews have focused on sedentary behavior in adults age 80 and older, sometimes called the "oldest old" (Abbatecola et al., 2015). The purpose of this paper was to conduct a systematic review of the literature to characterize the volume of objectively measured sedentary behavior and to identify any factors that are known to influence sedentary behavior in community-dwelling adults aged 80 and older. This provides an important basis for understanding sedentary behavior in this population and serves as a comparison for the portion of this dissertation focusing on sedentary behavior in assisted living residents (paper 3), most of whom are in the "oldest old" age group.

Paper 2 Statement of the Problem and Purpose

Individuals with chronic obstructive pulmonary disease (COPD) tend to be less active than the general population and this sedentary lifestyle may contribute to risk of hospitalization and mortality (Garcia-Aymerich et al., 2006; Vorrink et al., 2011). Accurate measurement of sedentary behavior is important for assessing associated health risks and effectiveness of interventions targeting sedentary behavior. ActiGraph accelerometers are commonly used to measure sedentary behavior in people with chronic disease, but the ActiGraph may misclassify standing time as sedentary behavior if little movement is detected (Kozey-Keadle et al., 2011). The ActivPAL, an inclinometer and accelerometer, is considered the gold standard for measuring sedentary behavior because it is able to detect body position (Kozey-Keadle et al., 2011). The optimal method for processing ActiGraph accelerometer data to measure sedentary behavior in adults with COPD is unknown and unique processing methods may be needed as their movements are likely slower. The purpose of this study was to conduct a secondary data analysis comparing ActiGraph vertical axis and vector magnitude processing methods, using two filters, three different non-wear algorithm lengths, and various sedentary behavior cut-points derived in other older adult populations, to gold standard (ActivPAL) measures of time spent in sedentary behavior and to identify an optimal method to be used in older adults with COPD. This paper relates to the overall dissertation theme as this population is an example of persons with chronic disease who are highly sedentary.

Paper 3 Statement of the Problem and Purpose

Older adults in assisted living are a less active subgroup of older adults (Moran et al., 2015) who spend excessive amounts of time in sedentary behavior (Resnick et al., 2011). Assisted living residents are at risk for sedentary behavior due to their age and health status

(Evenson et al., 2014; Koolhaas et al., 2017; Sartini et al., 2015), but this risk is amplified as they often rely on staff to complete activities for them, even if they are still able (Resnick et al., 2011). Residents are therefore at high risk for declines in health and physical function, which may necessitate transfer to higher levels of care (Giuliani et al., 2008). Physical activity programs in assisted living facilities are inadequate; usually only chair exercises are offered (Mihalko & Wickley, 2003). In addition, the population of adults aged 85 and older, the age group most at risk for needing long-term care such as assisted living, is expected to triple from 6.3 million in 2015 to over 18.9 million in 2050 (Harris-Kojetin et al., 2019). There is a great need for programs focused on realistic goals of decreasing sedentary time and increasing light physical activity. The unique social environment of assisted living communities provides a valuable opportunity for behavior change as residents interact closely with one another and staff (Mihalko & Wickley, 2003). The purpose of this project was to involve residents of assisted living in the development of a proposed intervention to reduce sedentary behavior and increase light physical activity by conducting qualitative interviews in which they were asked for feedback on the proposed intervention. Broader contextual factors that may influence intervention implementation were also explored.

Specific Aims

Aim 1 (Paper 1)

Characterize sedentary behavior in community-dwelling adults age 80 and older by conducting a systematic review focused on the volume of sedentary behavior (hours/day) and any factors associated with sedentary behavior in this population.

Aim 2 (Paper 2)

Identify optimal methods for processing objectively measured sedentary behavior data by analyzing ActiGraph vertical axis and vector magnitude data with multiple combinations of filters, non-wear algorithm lengths, and cut-points and by comparing ActiGraph estimates to ActivPAL-measured sedentary time in inactive people with chronic obstructive pulmonary disease.

Aim 3 (Paper 3)

Gather feedback from assisted living residents on a proposed Active for Life in Assisted Living intervention by conducting one-on-one interviews. A secondary aim was to explore contextual factors that may influence how the intervention will be implemented with this population.

Review of the Literature

This chapter begins with reviews of interventions targeting physical activity and sedentary behavior in the general older adult population. Next will be a description of the assisted living setting and physical activity levels of older adults in assisted living. Factors known to influence physical activity and sedentary behavior in assisted living residents will be presented, followed by physical activity and sedentary behavior interventions with the assisted living population. Various methods for measuring sedentary behavior will be discussed, as well as considerations and challenges related to each measurement type. Finally, the theoretical foundations for this dissertation project will be described.

Physical Activity Interventions in Older Adults

Although the primary focus of this dissertation is sedentary behavior, interventions focused on physical activity in older adults will be reviewed. Physical activity and exercise interventions have been more widely tested than sedentary behavior interventions, and although they have a slightly different focus, are closely related. Multiple systematic reviews and meta-analyses have synthesized the evidence on the effectiveness of physical activity interventions on a number of outcomes. These reviews include studies conducted in general older adult populations, mostly community-dwelling older adults. Most reviews defined older adults as age ≥60 or ≥65. There is strong evidence that physical activity interventions are effective for improving physical activity levels of older adults (Burton et al., 2017; Conn et al., 2003; Hill et al., 2015; Moore et al., 2016; Olanrewaju et al., 2016; Oliveira et al., 2017; Taylor et al., 2021). Evidence also suggests that physical activity or exercise interventions have positive effects on measures of physical function and physical abilities, including six-minute walk distance (Burton et al., 2017), Timed Up and Go test (Chase et al., 2017; Okubo et al., 2017), balance (Chou et al., 2012; Di Lorito et al., 2021; Larsen et al., 2013; Okubo et al., 2017; Weber et al., 2018), gait speed (Chou et al., 2012; Di Lorito et al., 2021; Giné-Garriga et al., 2014; Gu & Conn, 2008; Lopopolo et al., 2006; Okubo et al., 2017; Plummer et al., 2015; Van Abbema et al., 2015), activities of daily living (Chou et al., 2012; Di Lorito et al., 2021; Roberts et al., 2017), sit to stand test (lower limb strength) (Gu & Conn, 2008; Hill et al., 2015; Liberman et al., 2017), stepping reaction time (Okubo et al., 2017), short physical performance battery score (Giné-Garriga et al., 2014), muscle strength (Chaabene et al., 2021; de Labra et al., 2015; Di Lorito et al., 2021; Hill et al., 2015; Larsen et al., 2013; Liberman et al., 2017; Weber et al., 2018; Zhao et al., 2017), and bone health (Pinheiro et al., 2020). A smaller number of reviews found mixed evidence on whether physical activity interventions improve physical function or strength in older adults (Burton et al., 2019; de Labra et al., 2015; Frost et al., 2017; Moore et al., 2016; Okubo et al., 2017). Evidence also suggests that physical activity interventions reduce fear of falling, fall rates, and fall-related injuries in older adults (Di Lorito et al., 2021; Kumar et al., 2016; Okubo et al., 2017; Sherrington et al., 2020; Weber et al., 2018; Zhao et al., 2017), although two reviews found mixed evidence or no overall effect on incidence of falls (de Labra et al., 2015; Hill et al., 2015). Some reviews have found physical activity interventions may have beneficial effects on cognition in older adults (Hoffmann et al., 2021; Olanrewaju et al., 2016; Yen & Chiu, 2021), while others have found mixed evidence (Di Lorito et al., 2021). Exercise does have positive effects on depressive symptoms (Di Lorito et al., 2021; Drazich et al., 2020; Miller et al., 2020; Moore et al., 2016; Yen & Chiu, 2021) and sleep (Vanderlinden et al., 2020) in older adults. Current evidence does not support the effect of physical activity interventions on life role participation (Beauchamp et al., 2017) and is mixed on whether exercise improves older adults' quality of life (Di Lorito et al., 2021). Reviews examining the sustainability of PA changes in older adults have found significant intervention effects at short-term and intermediate follow-up, but not at one or two years (Grande et al., 2020; Sansano-Nadal et al., 2019).

Several systematic reviews have examined whether characteristics of physical activity interventions influence participant adherence or intervention effectiveness in older adults. Various types of physical activity interventions are effective for improving physical activity of older adults, including peer-delivered, group, home-based, community-based, health coaching, and digital behavior change interventions such as monitor-based, eHealth, and mobile health app interventions (Burton et al., 2017; Chaabene et al., 2021; Conn et al., 2003; Hill et al., 2015; Larsen et al., 2019; Moore et al., 2016; Muellmann et al., 2018; Olanrewaju et al., 2016; Oliveira et al., 2017; Stockwell et al., 2019; Yerrakalva et al., 2019). Interventions may have a larger effect size when delivered in a group setting (Conn et al., 2003). There is mixed evidence on whether supervised physical activity interventions are more effective than interventions utilizing remote feedback (Geraedts et al., 2013; Lacroix et al., 2017; Picorelli et al., 2014). Intervention effectiveness may be influenced by the intensity of activity that is targeted. Interventions targeting low or moderate physical activity are most effective for improving physical activity of older adults (Conn et al., 2003; Zubala et al., 2017), but high intensity activity may be more effective for improving physical functioning (de Vries et al., 2012). One meta-analysis compared effect sizes of various types of exercise interventions in older adults and found the largest effect sizes for resistance training, meditative movement interventions, and active video games (Di Lorito et al., 2021).

Interventions that utilize a theory are found to be more effective than interventions that do not (Chase, 2015). In addition, interventions using cognitive and behavioral strategies may be the most effective (Chase, 2013, 2015). Self-efficacy has been the most operationalized theoretical construct in physical activity interventions for older adults (Chase, 2013). Some evidence suggests that self-regulation may not be an effective strategy for improving physical activity in older adults (French et al., 2014), while another review found that interventions incorporating self-monitoring were more effective (Conn et al., 2003). Evidence suggests that older adults may be more motivated to be active by enjoyment, social interactions and support, and short-term outcomes than they are by focusing on long-term health outcomes (Devereux-Fitzgerald et al., 2016; Olanrewaju et al., 2016; Zubala et al., 2017). Additionally, adherence to exercise programs may be influenced by several personal characteristics, including demographics, health status, physical abilities, and psychosocial factors (Picorelli et al., 2014).

Sedentary Behavior Interventions in Older Adults

Fewer individual studies have tested interventions focused on decreasing sedentary behavior in general older adult populations (primarily community-dwelling) (n=31) (Bårdstu et al., 2021; Barone Gibbs et al., 2017; Britten et al., 2017; Burke et al., 2013; Chang et al., 2014; Compernolle et al., 2020; Crombie et al., 2021; Fanning et al., 2016; Fitzsimons et al., 2013; Gardiner, Eakin, et al., 2011; Kerr et al., 2016; Koltyn et al., 2019; Lewis et al., 2016; Lyons et al., 2017; Maher et al., 2017; Matei et al., 2015; Matson et al., 2018; Müller et al., 2016; Mutrie et al., 2012; Owari et al., 2019; Roberts et al., 2019; Rooijackers et al., 2021; Rosenberg et al., 2020; Rosenberg et al., 2015; Rosenberg et al., 2017; Suboc et al., 2014; Swartz et al., 2018; Tosi et al., 2021; Toto et al., 2012; Wang et al., 2020; White et al., 2017). Most of these studies included adults age 60 and older, although some used minimum age criteria of 50, 55, or 65 years. These interventions took place in both community and home-based settings and utilized diverse modes of delivery including in-person, technology-based, and mixed modes. They included a mix of individual and group-based activities. Studies utilized behavioral strategies such as counselling, self-monitoring, goal setting, feedback, action plans, social support, prompts, group discussion, and written material. Social cognitive theory was the most common theory that guided intervention strategies; other theories utilized were self-determination, habit formation, and behavioral choice.

Intervention sample sizes ranged from 10-275 participants. Most had modest sample sizes of 20-60; seven were tested in samples of greater than 100 participants. Of the 31 interventions found in the literature, 18 provided some evidence of short-term improvements in time spent in sedentary behavior (Britten et al., 2017; Burke et al., 2013; Chang et al., 2014; Crombie et al., 2021; Fitzsimons et al., 2013; Gardiner, Clark, et al., 2011; Kerr et al., 2016; Koltyn et al., 2019;

Lewis et al., 2016; Lyons et al., 2017; Maher et al., 2017; Matei et al., 2015; Mutrie et al., 2012; Owari et al., 2019; Rosenberg et al., 2020; Rosenberg et al., 2015; Swartz et al., 2018; Tosi et al., 2021). Of these 18 studies, 13 used objective measures of sedentary behavior, enhancing confidence in results (Crombie et al., 2021; Fitzsimons et al., 2013; Gardiner, Eakin, et al., 2011; Kerr et al., 2016; Koltyn et al., 2019; Lewis et al., 2016; Lyons et al., 2017; Mutrie et al., 2012; Owari et al., 2019; Rosenberg et al., 2020; Rosenberg et al., 2015; Swartz et al., 2018; Tosi et al., 2021). Twenty of the identified interventions to reduce sedentary behavior in older adults used a randomized controlled or randomized pilot design (65%) (Bårdstu et al., 2021; Barone Gibbs et al., 2017; Burke et al., 2013; Crombie et al., 2021; Fanning et al., 2016; Kerr et al., 2016; Lyons et al., 2017; Maher et al., 2017; Matson et al., 2018; Müller et al., 2016; Mutrie et al., 2012; Owari et al., 2019; Roberts et al., 2019; Rooijackers et al., 2021; Rosenberg et al., 2020; Suboc et al., 2014; Swartz et al., 2018; Tosi et al., 2021; Wang et al., 2020; White et al., 2017). Eleven of the 20 randomized trials found the intervention to be effective for reducing sedentary behavior (Burke et al., 2013; Crombie et al., 2021; Kerr et al., 2016; Lyons et al., 2017; Maher et al., 2017; Mutrie et al., 2012; Owari et al., 2019; Rosenberg et al., 2020; Swartz et al., 2018; Tosi et al., 2021; Wang et al., 2020). In all studies in which the experimental group decreased objectively-measured sedentary time, magnitudes of sedentary time reduction at short-term follow-up ranged from 24-68 minutes/day, with one outlier study finding a reduction of 130 minutes/day. Only two studies included long-term follow-up and did not find significant reductions in sedentary time (Bårdstu et al., 2021; Fanning et al., 2016). Six of the 18 studies that were effective for reducing sedentary time also measured intervention effects on physical function (Britten et al., 2017; Crombie et al., 2021; Koltyn et al., 2019; Mutrie et al., 2012; Rosenberg et al., 2020; Rosenberg et al., 2015); four of these found improvements in measures such as the Short Physical Performance Battery and its components (gait speed, balance, chair stands) (Crombie et al., 2021; Koltyn et al., 2019; Rosenberg et al., 2015) and the Timed Up and Go test (Britten et al., 2017).

Three recent literature reviews have summarized the evidence for interventions to reduce sedentary behavior in older adults ≥60 years. Petruvski et al. conducted a scoping literature review and identified 20 articles that reported results for this type of intervention; 80% of those found a significant change in sedentary behavior (Petrusevski et al., 2020). A systematic review by Chase et al. included 17 studies and found that most interventions were theory-driven and included strategies such as education, self-monitoring, and goal setting (Chase et al., 2020). Chase et al. also conducted a meta-analysis with 8 studies and found that interventions significantly reduced sedentary time, with a small effect size (d=-0.25). Chastin et al. conducted a systematic review of randomized controlled trials aimed at reducing sedentary time in older adults (Chastin et al., 2021). Pooled evidence of 7 trials found they may reduce sedentary time by a mean of 44.91 minutes/day.

Overall, individual studies and literature reviews indicate that several interventions have shown potential for reducing short-term sedentary behavior in older adults, but larger trials are needed with strategies for long-term maintenance of sedentary behavior reduction.

Assisted Living: Environment and Physical Activity

Assisted living facilities provide 24-hour supportive care services for primarily older adult populations (Mollica et al., 2012). They provide an intermediate level of care for older adults with functional limitations who do not need the costlier level of medical supervision provided by nursing homes (Houser et al., 2018; Mollica et al., 2012). Unlike nursing homes, assisted living facilities are not federally defined or regulated, so services may vary at each facility (Gregory et al., 2007). Typical services provided include meals, personal care, housekeeping, and other activities of daily living and instrumental activities of daily living (Mollica et al., 2012). Accommodations also vary, with some facilities offering apartments and others offering private or shared rooms (Street et al., 2007). Assisted living is intended to provide a home-like environment and allow residents to maintain control and independence as much as possible (Mihalko & Wickley, 2003). There are approximately 28,900 assisted living facilities in the United States with almost one million licensed beds (Harris-Kojetin et al., 2019). The demand for assisted living care will likely increase drastically in coming years, as the population of older adults age 85 and older in the United States is expected to triple from 2015 to 2050 (Harris-Kojetin et al., 2019). Changing family dynamics in the United States will also lead to increased need for assisted living services as the generations currently crossing into older adulthood are more likely to have fewer or no children and more likely to be single than previous older adult generations (Posey, 2017).

Assisted living facilities are a unique, defined social environment in which residents interact daily (Mihalko & Wickley, 2003). Often, a move to assisted living is prompted by health problems or the death of a spouse (Street et al., 2007). When older adults transition to assisted living, there is opportunity for them to form new social ties (Abbott et al., 2015). Evidence suggests that residents' sense of community is related to psychological well-being and that social relationships with other residents and staff within the facility become more predictive of their well-being than external relationships (Plys & Qualls, 2020; Street et al., 2007). Residents may provide emotional and health-related support to other residents within their social networks (Abbott et al., 2015). There is opportunity for residents' interpersonal relationships to influence their physical activity behavior as they encourage one another to participate in activity or staff members encourage residents to perform activities (Holmes et al., 2017). Social groups and social norms within assisted living may be an important point of intervention for promoting physical activity (Mihalko & Wickley, 2003). The unique social environment in which residents interact closely with one another and staff provides a valuable opportunity for behavior change (Mihalko & Wickley, 2003).

Residents in assisted living are known to be highly sedentary, spending between 8.5-10.9 hours of the waking day in sedentary behavior (Leung et al., 2017; Park et al., 2017; Voss, Pope, Larouche, et al., 2020); a scoping review found a mean sedentary time of 9.5 hours/day in this population (Leung et al., 2021). Qualitative studies have found that older adults in assisted living may believe sitting is a natural consequence of aging (Kotlarczyk et al., 2020; Voss, Pope, & Copeland, 2020). However, they generally have a negative perception of sedentary behavior and recognize its harmful effects (Kotlarczyk et al., 2020; Voss, Pope, & Copeland, 2020). Both residents and staff view physical activity as important for maintaining various aspects of health, physical function, and overall well-being (Mahrs Träff et al., 2017; Phillips & Flesner, 2013; Vos, 2017). However, there are some documented misconceptions among assisted living residents about what counts as physical activity and sedentary behavior. Residents may not consider sedentary activities to be harmful if they involve social interaction or cognitive engagement (Kotlarczyk et al., 2020; Voss, Pope, & Copeland, 2020). They may perceive themselves as being very active, but that assessment may be based on misconceptions that some seated activities count as physical activity (Vos et al., 2019). Residents and staff may also define physical activity differently. One study found that residents defined physical activity as exercise, hobby, or pastime, while the staff defined physical activity in terms of everyday activities (Mahrs Träff et al., 2017). These studies suggest that there may be a need to educate assisted living residents about physical activity and sedentary behavior. Interventions to reduce sedentary behavior may need to focus on types of sedentary activities that residents do not perceive to be beneficial.

Physical activity programs in assisted living may be a valuable tool to help residents maintain their functional abilities (Lu, 2010). Functional decline and increased care requirements lead to transfer from assisted living to a higher level of care, such as a nursing home (Phillips et al., 2017). Maintaining function is very important because residents would prefer to stay in assisted living, a setting with more autonomy (Williams & Warren, 2008). Assisted living facilities may offer some exercise activities, but often only chair exercises (Mihalko & Wickley, 2003). There is evidence suggesting that chair exercises may have some benefits for physical function (Klempel et al., 2021), but this type of program will not promote a reduction in sedentary behavior or increase in light physical activity throughout the day. While chair-based exercise may be appropriate for very frail older adults who cannot participate in other physical activities, older adults who are able to participate in more challenging and active classes should do so (Robinson et al., 2016). There have been few studies focused on reducing sedentary behavior for older adults in assisted living (reviewed below).

Factors Influencing Sedentary Behavior and Physical Activity in Assisted Living

A number of factors can influence levels of physical activity and sedentary behavior in older adults in assisted living. Health and mobility issues contribute to lower levels of physical activity and exercise and higher levels of sedentary behavior in this population (Bender et al., 2021; Chen, 2010; Y.-M. Chen et al., 2015; Phillips & Flesner, 2013; Vos et al., 2019; Voss, Pope, & Copeland, 2020). Specific physical health factors that may influence activity of residents include pain, fatigue, impaired sight and hearing, musculoskeletal problems, chronic neurological conditions, and acute illness (Bender et al., 2021; Phillips & Flesner, 2013; Voss, Pope, & Copeland, 2020). Mental health factors, including anxiety and depression, may also influence sedentary behavior and physical activity in this population (Y.-M. Chen et al., 2015; Park et al., 2017). Assisted living residents view physical frailty, poor balance, and mobility limitations as barriers to being active (Chen, 2010; Kotlarczyk et al., 2020; Voss, Pope, & Copeland, 2020) and evidence suggests that functional status contributes to their levels of sedentary behavior and physical activity (Y.-M. Chen et al., 2015). Conversely, maintaining health, preventing loss of mobility, and avoiding discomfort from sitting too much may be motivating for older adults in assisted living to be more active (Vos et al., 2019; Voss, Pope, & Copeland, 2020).

Psychological factors also influence the activity behaviors of assisted living residents. Fear of falling significantly contributes to sedentary behavior of residents (Kotlarczyk et al., 2020; Phillips & Flesner, 2013; Voss, Pope, & Copeland, 2020). Some residents may lack motivation for being active or feel that physical activity takes too much effort (Phillips & Flesner, 2013; Voss, Pope, & Copeland, 2020). In addition, they may have misconceptions about physical activity and aging. They may believe that sedentary behavior is an inevitable part of aging or that physical activity is not important in older age (Chen, 2010; Voss, Pope, & Copeland, 2020). Residents may find certain sedentary behaviors to be highly enjoyable (Voss, Pope, & Copeland, 2020). One factor that enhances physical activity levels of residents is higher self-efficacy for exercise (Y.-M. Chen et al., 2015; Phillips et al., 2018). Some residents may feel an obligation to be active or that being active is part of their identity (Voss, Pope, & Copeland, 2020).

Activity behaviors of assisted living residents are influenced by social factors. Engaging in social activities within their facility may provide opportunities for being active (Voss, Pope, & Copeland, 2020). Receiving encouragement for being active, such as from family, health care providers, or assisted living staff, positively impacts physical activity (Holmes et al., 2017; Phillips et al., 2018; Voss, Pope, & Copeland, 2020). Having a companion to be active with provides motivation for reducing sedentary time (Voss, Pope, & Copeland, 2020). On the other hand, social norms of inactivity within assisted living may serve as a barrier to physical activity (Voss, Pope, & Copeland, 2020). One study found that residents who were less satisfied with their relationships with staff actually spent more time in physical activity (Holmes et al., 2017).

Several factors related to the assisted living environment may influence the physical activity and sedentary behavior of its residents. As previously mentioned, the nature of assisted living and the services it provides means that residents do not have to perform many activities of daily living that would have afforded them opportunities for physical activity (Kotlarczyk et al., 2020; Voss, Pope, & Copeland, 2020). Activities offered by the facility may provide opportunities for being active, but a lack of activities on weekends and evenings may contribute to sedentary time (Holmes et al., 2017; Voss, Pope, & Copeland, 2020). Additionally, timing preferences may hinder participation in physical activities, for example if chair exercises are offered too early in the morning (Phillips & Flesner, 2013). Some facilities may have limited or no space for exercise and exercise equipment (Chen, 2010; Phillips & Flesner, 2013) and poor space configuration may hinder participation in group exercises (Bender et al., 2021). When facilities do have exercise equipment, residents may not know how to properly use it or they may be deterred by policies requiring physician permission or staff supervision (Phillips & Flesner, 2013).

A few miscellaneous factors have additionally been found to influence assisted living residents' physical activity and sedentary behavior. Men in assisted living tend to spend more time sedentary than women (Leung et al., 2017). Past physical activity participation influences their current physical activity (Y.-M. Chen et al., 2015). Staffing turnover or shortages in assisted living may impact residents' ability to receive assistance ambulating to and from exercise classes (Bender et al., 2021). A lack of transportation is another barrier to reducing sedentary time for some assisted living residents, making it more difficult to do activities outside of their facility (Voss, Pope, & Copeland, 2020). In addition, poor weather contributes to sedentary behavior because many residents enjoy walking outside of the facility (Voss, Pope, & Copeland, 2020).

Sedentary Behavior and Physical Activity Interventions in Assisted Living

Only three known interventions have been tested in the assisted living setting with a goal of decreasing sedentary behavior and they are all small pilot or feasibility studies (Dillon & Prapavessis, 2020; Naber et al., 2020; Voss, Pope, Larouche, et al., 2020). Voss et al. conducted a pilot study of an intervention that addressed four levels of the social ecological model (organization/policy, physical environment, social environment, and individual behavior) (Voss, Pope, Larouche, et al., 2020). Feasibility and acceptability of the intervention were supported, but overall residents did not significantly decrease their sitting time. Residents at one site did decrease their sitting time by 37 minutes/day, while residents at another site increased their sitting time by 24 minutes/day after the intervention. Dillon et al. assessed the feasibility of decreasing sitting time using a prompting device in older adults with mild to moderate cognitive impairment in assisted living in a pilot randomized controlled trial (Dillon & Prapavessis, 2020). The intervention group increased their light physical activity by 133 minutes/week and the intervention also had positive effects on cognitive function, mobility, physical function, and mental health. The next intervention to decrease sedentary behavior in assisted living was conducted by Naber et al. and was an occupational therapy intervention using individual goal setting (Naber et al., 2020). The intervention did not decrease sedentary behavior, but did reduce pain. One additional sedentary behavior intervention was conducted with both independent and assisted living residents, but is relevant because it included older adults with moderate to low physical function (Thralls Butte & Levy, 2020). This intervention used techniques based on social cognitive theory and there were two intervention groups: one focused on increasing sit-to-stand transitions and one focused on reducing total sitting time. Both groups decreased their sedentary time by a mean 1.3 hours/day and also improved physical function (Thralls Butte & Levy, 2020).

Other interventions in the assisted living setting (not focused on sedentary behavior) have targeted various modes of exercise or physical activity (Alvarez et al., 2015; Beato et al., 2018; Chao et al., 2013; Chen et al., 2021; Greene et al., 2017; Herbert & Greene, 2001; Hummer et al., 2015; Johnson et al., 2013; Kluge et al., 2014; Knott et al., 2021; Lauze et al., 2017; Naylor et al., 2000; Resnick, Boltz, Galik, Fix, et al., 2021; Resnick, Boltz, Galik, & Zhu, 2021; Resnick et al., 2011; Resnick et al., 2009; Resnick et al., 2016; Stanmore et al., 2019; Sung, 2009; Taylor et al., 2003; Van Roie et al., 2017; Vanroy et al., 2019). These include exergames (technology-based gaming system leading exercises and providing feedback), walking, function-focused care, physical therapy, Tai Chi, cycling, sit-to-stand exercises, and combination programs with laughter, flexibility, strength, and balance exercises.

Five physical activity or exercise intervention studies measured physical activity as an outcome (Lauze et al., 2017; Resnick, Boltz, Galik, Fix, et al., 2021; Resnick et al., 2011;

Resnick et al., 2009; Van Roie et al., 2017). Two studies found significant intervention effects on physical activity, but used self-reported measures (Lauze et al., 2017; Resnick et al., 2009). One study did find significant effects on objectively-measured energy expenditure and self-reported moderate physical activity, but not on self-reported light physical activity (Van Roie et al., 2017).

Physical activity or exercise studies measured outcomes of interest other than levels of physical activity. Four studies measured whether the physical activity intervention influenced residents' self-efficacy and outcome expectations (Chao et al., 2013; Greene et al., 2017; Resnick et al., 2011; Resnick et al., 2009). Only one study found positive effects on outcome expectations (Greene et al., 2017) and no interventions were effective for increasing self-efficacy. One possible explanation for these findings could be that the studies did not measure a true baseline self-efficacy, as participants may overestimate their self-efficacy before starting a physical activity program (McAuley et al., 2011). Several studies found positive intervention effects on other outcomes, including functional measures such as gait, walking speed, short physical performance battery score, timed-up-and-go test, balance, flexibility, activities of daily living independence, and falls (Alvarez et al., 2015; Beato et al., 2018; Chao et al., 2013; Greene et al., 2017; Knott et al., 2021; Lauze et al., 2017; Resnick, Boltz, Galik, & Zhu, 2021; Resnick et al., 2009; Resnick et al., 2016; Stanmore et al., 2019; Sung, 2009; Taylor et al., 2003; Van Roie et al., 2017). Some studies also found evidence of improved 6-minute walk distance, aerobic endurance, grip strength, and lower body strength after intervention (Greene et al., 2017; Kluge et al., 2014; Resnick et al., 2009; Sung, 2009; Van Roie et al., 2017). There is evidence that assisted living residents' sleep, memory, and pain may be improved through physical activity intervention (Naylor et al., 2000; Stanmore et al., 2019). In summary, interventions in assisted living may influence important outcomes related to physical function and fitness, but more work is needed related to intervention effects on self-efficacy.

Only six sedentary behavior or physical activity intervention studies in assisted living have utilized a randomized controlled design (Dillon & Prapavessis, 2020; Lauze et al., 2017; Resnick et al., 2011; Sung, 2009; Thralls Butte & Levy, 2020; Van Roie et al., 2017). Five of these were cluster randomized by facility or facility wings (Dillon & Prapavessis, 2020; Resnick et al., 2011; Sung, 2009; Thralls Butte & Levy, 2020; Van Roie et al., 2017) and one study randomized residents within the same facilities, creating concerns of contamination (Lauze et al., 2017).

In summary, there have been few high-quality intervention studies designed to reduce sedentary behavior or promote physical activity of assisted living residents. Some studies have shown preliminary evidence for improving activity behaviors, functional outcomes, fitness, and other health outcomes, but additional work is needed in this area.

Measurement of Sedentary Behavior

Various subjective and objective tools have been used to quantify sedentary behavior and there are important issues or considerations related to each type of measure. Historically, the most commonly used measures were self-reported. Self-report measures ask participants to describe their usual behavior, recall past behavior, or keep a log of current behavior (Healy et al., 2011). Objective measures of sedentary behavior are increasingly being used. Objective measures commonly include accelerometers that measure the intensity and duration of movements, as well as inclinometers that measure body position.

Self-Report Measures

There are several self-report measures that have been used to measure sedentary behavior. This review will focus on questionnaires that have been psychometrically tested in older adult populations. Questionnaires and evidence for their validity and reliability are shown in Table 1.1. This table does not include all available evidence for their psychometric properties, but select studies with relevant older adult populations are shown. Questionnaires include the Yale Physical Activity Survey for Older Adults (YPAS), the Community Health Activities Model Program for Seniors (CHAMPS) survey, the Measure of Older Adults' Sedentary Time (MOST) (Gardiner, Clark, et al., 2011), an adult version of the Multimedia Activity Recall for Children and Adolescents (MARCA), the International Physical Activity Questionnaire (IPAQ) (Aguilar-Farias et al., 2015; Cleland et al.; Gennuso et al., 2015; Ryan et al., 2018), the Sedentary Behavior Questionnaire (SBQ) (Sansano-Nadal et al., 2021), Active-Q (Bonn et al., 2015), and the Physical Activity and Sedentary Behavior Questionnaire (PASB-Q) (Fowles et al., 2017). Three other unnamed measures of self-reported sedentary behavior were also found in the literature (Aguilar-Farias et al., 2015; Van Cauwenberg et al., 2014; Visser & Koster, 2013). The Physical Activity Scale for the Elderly (PASE) includes one item about sedentary time (Washburn et al., 1993). However, this measure is not included in Table 1.1 because psychometric properties are not available specifically for this item.

There is evidence for the test-retest reliability of each questionnaire; intraclass correlation coefficients (ICC) supported moderate to high test-retest reliability (0.52-0.96) (Aguilar-Farias et al., 2015; Bonn et al., 2015; Fowles et al., 2017; Gardiner, Clark, et al., 2011; Gennuso et al., 2015; Rosenberg et al., 2010; Van Cauwenberg et al., 2014; Visser & Koster, 2013). One study reported test-retest reliability as a correlation of 0.26 between repeated measures at two timepoints (Ryan et al., 2018). Internal consistency reliability has rarely been reported for these sedentary behavior questionnaires; the SBQ was found to have strong internal consistency in a sample of adults (Cronbach's α=0.92) (Araujo et al., 2021).

Validity of self-reported measures of sedentary behavior was typically tested by comparing questionnaire results to objectively measured sedentary behavior. With the exception of two questionnaires, the self-reported measures tended to underestimate volume of sedentary behavior compared to objective measures (Aguilar-Farias et al., 2015; Cleland et al.; Gardiner, Clark, et al., 2011; Gennuso et al., 2015; Van Cauwenberg et al., 2014). Volume of underestimation ranged from 1.2 to 5.2 hours/day, with most of these studies finding that subjects underestimated their sedentary behavior by about 3 hours/day. The MARCA questionnaire was found to overestimate sedentary behavior (mean bias was 0.82-1.66 hours/day) (Aguilar-Farias et al., 2015). The Visser & Koster questionnaire (2013) found no significant difference between mean self-reported sedentary time (10.4 hours/day) and mean objective sedentary time (10.2 hours/day), but correlation between the two methods was moderate. Correlation between self-report and objective measures of sedentary time ranged from 0.14-0.70, but most studies found weak agreement.

Evidence indicates the MARCA questionnaire had the strongest correlation with objectively measured sedentary behavior. However, most self-report measures of sedentary behavior do not meet acceptable levels of validity in older adults. There can be issues related to recall with many self-report measures, but it is thought that sedentary behavior is very difficult to recall because it is typically not a planned behavior and it tends to occur multiple times per day in the context of an individual's daily activities (Gennuso et al., 2015). In contrast, there is evidence that behaviors such as moderate to vigorous physical activity, which are usually planned, may be more accurately recalled (Ryan et al., 2018). Because sedentary behavior is viewed as a negative health behavior, social desirability may also influence older adults to underreport time spent sedentary (Ryan et al., 2018; Van Cauwenberg et al., 2014).

Table 1.1 Validity and reliability of self-report measures used to measure sedentary behavior in older adults. The number of items reflects the items the study used for sedentary behavior analysis, not necessarily the number of items in the total scale. Studies reporting validity compared the self-reported measure to an objective measure of sedentary behavior (accelerometer or ActivPAL). Validity and reliability are specific to the sedentary behavior items and were evaluated in older adult populations unless otherwise noted.

Measure	Number of Items	Concurrent Validity	Reliability
Yale Physical Activity Survey for Older Adults (YPAS) (Gennuso et al., 2015)	1	• 8.6% agreement with ActiGraph and kappa value = −0.0003 • Underestimated sedentary time (not quantified)	Test-retest reliability: ICC=0.59
Community Health Activities Model Program for Seniors (CHAMPS) Questionnaire (Gennuso et al., 2015)	9	• Lin's r=0.005, Pearson's r=0.14 • Underestimated sedentary time by 5.21 hours/day	Test-retest reliability: ICC=0.64
Unnamed questionnaire by Van Cauwenberg (Van Cauwenberg et al., 2014)	12	• Spearman's correlation=0.30 • Underestimated sedentary time by 82 minutes/day	Test-retest reliability: ICC=0.77
Measure of Older Adults' Sedentary Time (MOST) (Gardiner, Clark, et al., 2011)	7	• Spearman's correlation=0.30 • Underestimated sedentary time by 3.6 hours/day	Test-retest reliability: ICC=0.52
Single Question (on weekday, weekend, yesterday) (Aguilar-Farias et al., 2015)	1	• Spearman's correlation=0.33 (for an average day) • Underestimated sedentary time by 3.53 hours/day	Test-retest reliability: ICC=0.79 (for an average day)

Adult version of Multimedia Activity Recall for Children and Adolescents (MARCA) (Aguilar-Farias et al., 2015)	2	• Spearman's correlation=0.63 (for an average day) • Overestimated sedentary time by 1.66 hours/day	Test-retest reliability: ICC=0.96 for "yesterday" and ICC=0.72 for "day before yesterday"
International Physical Activity Questionnaire (IPAQ)	2	• Spearman's correlations were 0.70 for weekdays and 0.26 for weekends (Cleland et al., 2018) • Spearman's correlation=0.29 (Ryan et al., 2018) • Underestimated sedentary time by approximately 3 hours/day (Cleland et al., 2018)	Test-retest reliability: Spearman's correlation=0.26 (Ryan et al., 2018)
Unnamed questionnaire (sum of 10 activities) (Visser & Koster, 2013)	10	• Spearman's correlation=0.35 using all 10 reported activities • Spearman's correlation=0.46 using 6 activities • No significant difference between self-reported and objective using all 10 activities • Underestimated sedentary time by 2.1 hours/day using 6 activities	Test-retest reliability: ICC=0.71 for 6 activities
Sedentary Behavior Questionnaire (SBQ) (Sansano-Nadal et al., 2021)	9	• Spearman's correlation=0.25 • Underestimated sedentary time by 72.9 minutes/day	Test-retest reliability: ICC=0.77 and ICC=0.85 on weekend and weekdays respectively[a] (Rosenberg et al., 2010) Internal consistency: Cronbach's α=0.92[a] (Araujo et al., 2021)

Active-Q (Bonn et al., 2015)	Varies based on their responses to this interactive questionnaire	• Spearman's correlation=0.19 • Underestimated sedentary time by 183 minutes/day	Test-retest reliability: ICC=0.80
Physical Activity and Sedentary Behavior Questionnaire (PASB-Q) (Fowles et al., 2017)	2	• Pearson's correlation=0.29 • Underestimated sedentary time by 5.8 hours/day	Test-retest reliability: ICC=0.85

[a] Reliability information reported from a sample of adults (could not be found in older adults)

Objective Measures

Due to the validity issues with self-reported measures of sedentary behavior, objective measures are increasingly being utilized (Kozey-Keadle et al., 2011). Objective measures are especially important for measuring sedentary behavior in assisted living residents as they may have misconceptions about what counts as physical activity (Vos et al., 2019). There are two main types of devices for measuring sedentary behavior objectively: accelerometers and inclinometers (Kozey-Keadle et al., 2011). Accelerometers will be discussed first.

Accelerometers can be used to measure time spent in various intensities of activity, including sedentary behavior and light, moderate, and vigorous physical activity (Tremblay et al., 2010). Acceleration may be measured in one, two, or three axes and data processing methods were historically developed for acceleration measured only in the vertical axis (Aguilar-Farias et al., 2014; John et al., 2010). Data are often reported as "activity counts," which reflect both intensity and frequency of movements over a specified period of time, expressed as counts per minute for vertical axis data and vector magnitude units per minute for triaxial data (Aguilar-Farias et al., 2014; Tryon & Williams, 1996). Accelerometers measure sedentary behavior as time spent below a certain threshold of activity counts per minute (Kozey-Keadle et al., 2011). Volume of sedentary behavior can be summed and expressed as minutes per day. Rather than using activity counts, researchers can choose to use raw data with acceleration units, which may provide additional information such as direction and orientation (Montoye et al., 2018). Participants are typically asked to wear an accelerometer for a specified period of time (often 7 days) during waking hours only. They are most often worn on the waist/hip or wrist. The most commonly used accelerometer in the United States is the ActiGraph. The ActiGraph will be the primary focus of this review, but other brand names include Actical, Active Style Pro, SenseWear Pro, Actiheart, and Hookie (Amagasa et al., 2017; Copeland et al., 2015; Ensrud et al., 2014; Schrack et al., 2018; Tsai et al., 2016). Reliability of the ActiGraph for measuring sedentary behavior is supported in older women (intraclass correlation coefficient of 0.93) (Pfister et al., 2017). Validity of the ActiGraph for measuring sedentary behavior showed weak correlation with direct observation (R^2=0.39) (Kozey-Keadle et al., 2011).

While many types of accelerometers use proprietary algorithms and treat data processing as a black box, ActiGraph allows researchers to modify procedures for data processing based on the population and activities that are being measured (Chen et al., 2007). When processing ActiGraph data, there are several decisions that must be applied related to type of data (vertical vs. vector magnitude), activity cut-points, non-wear algorithms, and filters.

Older ActiGraph models had a single axis or dual axis and usually measured acceleration in the vertical axis, but newer models are triaxial and measure acceleration in three axes (John et al., 2010). With the triaxial models, a decision must be made whether to use only the vertical data or the triaxial data, referred to as vector magnitude data (Aguilar-Farias et al., 2014). There has been less work to develop processing methods for vector magnitude data. Cut-points for vector magnitude data would not be the same as those commonly used for vertical axis data.

Cut-points are used to define thresholds of counts per minute for various activity levels. Cut-points are often derived by comparing activity counts to energy expenditure through calorimetry or by comparing activity counts to another gold standard device such as the ActivPAL. The most commonly used cut-point to define sedentary behavior is <100 counts per minute. However, evidence is mixed regarding whether this cut-point is optimal. Some studies suggest that the best cut-point may be as low as 22 or 25 counts per minute (Aguilar-Farias et al., 2014; Koster et al., 2016), while another study suggests it may be 150 counts per minutes (Kim et al., 2015). It is likely that optimal cut-points may be population specific due to different behavior patterns.

Non-wear algorithms are used to identify periods of time when the device was likely removed. The algorithms identify periods of little or no activity and remove them from the data. The choice of non-wear algorithm length may have important implications for sedentary time. If participants spend extended lengths of time in sedentary behavior, the algorithm may misclassify that time as non-wear. Two commonly used algorithms are the Troiano and Choi algorithms. The Troiano algorithm identifies non-wear time as periods of at least 60 minutes of consecutive zeros, while allowing for up to two minutes of counts ≤100 counts per minute (Chudyk et al., 2017). The Choi algorithm identifies non-wear time as periods of at least 90 minutes of consecutive zeros, while allowing for up to two minutes of non-zero counts if there are 30 consecutive minutes of zero counts upstream or downstream from the interruption (Chudyk et al., 2017). The Choi algorithm is newer and was developed to improve upon the Troiano algorithm (Choi et al., 2011). It has been found to decrease non-wear time misclassification (Choi et al., 2011). An alternative to using non-wear algorithms is to determine non-wear time using proximity sensors found in newer ActiGraph models, but these sensors may not accurately detect wear and non-wear time (Arguello et al., 2018).

In newer ActiGraph models, there is a choice between the normal filter and a low frequency extension filter. The low frequency extension filter was designed to detect lower intensity movements and has been recommended for slower moving populations, such as older adults. Evidence suggests that filter choice impacts sedentary behavior estimates, but it is not known which filter is most valid for processing sedentary behavior data.

The four processing methods discussed above may impact sedentary behavior estimates. Unfortunately, there is no standardized protocol for processing ActiGraph data for sedentary behavior. There are additional challenges to consider when using accelerometers to measure sedentary behavior. Because the devices may be removed for various reasons, there may be data loss if participants forget to put them on again. There is also a possibility that time spent standing without movement may be misclassified as sedentary time (Kozey-Keadle et al., 2011). Newer ActiGraph models include an inclinometer that could help to detect body position, but this function may not accurately classify behaviors (Carr & Mahar, 2012).

The ActivPAL device is an inclinometer, as well as an accelerometer. It is a small rectangular device that is taped to the front of the thigh and can distinguish between time spent sitting/lying (sedentary), standing, and stepping. It distinguishes posture by measuring static acceleration and thigh orientation and uses dynamic acceleration to measure stepping activity. Software is used to summarize activity events over specified periods of time. Ultimately, researchers are able to quantify minutes of sedentary behavior per day. It is considered the gold standard for sedentary behavior because of its ability to detect body position. It has shown very strong correlation with direct observation of time spent sitting (R^2=0.94) (Kozey-Keadle et al., 2011). In addition, the ActivPAL was able to detect reductions in sitting time, while the ActiGraph was not (Kozey-Keadle et al., 2011). Test-retest reliability of the ActivPAL for measuring sedentary behavior has also been supported (ICC=0.93) (Pfister et al., 2017).

The ActivPAL is worn twenty-four hours per day and can be waterproofed so that subjects may keep it on for bathing or other water activities. This minimizes data loss issues that may occur with other types of devices. Because the definition of sedentary behavior does not include sleep time, researchers need to identify waking hours within the 24-hour data. Most studies ask participants to keep logs recording what times they go to bed and wake up while wearing the device (Edwardson et al., 2017). This method works well when participants are compliant with completing the logs, but some studies have reported compliance issues, such as only 45% completion rate in older adults in residential care (Reid et al., 2013). Researchers may also choose to visually examine data to determine probable waking and sleeping times (Edwardson et al., 2017). This method is likely not optimal because it is impossible to distinguish long periods of waking sedentary activities from sleeping behavior without any contextual information. Other studies have used a standardized waking period, such as from 0700-2300. This likely results in lower quality data because it assumes a regular, nocturnal sleep pattern (Edwardson et al., 2017). A newer method is the use of automated algorithms that identify specified patterns in the data that likely indicate periods of sleep (van der Berg et al., 2016). Two algorithms have shown strong agreement with self-logged sleeping time in adult populations (van der Berg et al., 2016; Winkler et al., 2012). Algorithms are being developed because they would reduce the burden of using logs on both participants and researchers. In addition, a new algorithm within the ActivPAL software identifies time in bed and has demonstrated 95% accuracy compared to diaries in older adults (Carlson et al., 2021).

In conclusion, there are several options for measuring sedentary behavior both subjectively and objectively. Each measurement tool is associated with unique issues or challenges. Current evidence suggests that the ActivPAL is the most valid and reliable tool for measuring sedentary behavior.

Theoretical Approach

Use of theory in health behavior interventions is important because it provides a statement of processes that are believed to regulate behavior and justifies intervention activities

(Rothman, 2004). It also helps to identify why an intervention did or did not have its intended effect (Rothman, 2004). Physical activity interventions in older adults are more effective if they are theory-based (Chase, 2015). A meta-analysis of physical activity randomized controlled trials in adults found that there were no differences in effect sizes between interventions using different theories, including Social Cognitive Theory, Transtheoretical Model, Theory of Planned Behavior, and Self-Determination Theory (Gourlan et al., 2016). One explanation for the lack of difference in effect size between theories is that they contain overlapping constructs (Gourlan et al., 2016). Each theory contains the construct of self-efficacy or a conceptually similar construct such as perceived behavioral control or competence (Gourlan et al., 2016). One review found self-efficacy to be the most commonly operationalized theoretical construct in older adult physical activity interventions (Chase, 2013). Self-efficacy is a highly modifiable construct, making it an appropriate choice for behavior intervention (McAuley et al., 2011).

Self-efficacy originated with Bandura's Social Cognitive Theory and is defined as the belief one has about what one can do under different circumstances with the skills one possesses (Bandura, 1997). Self-efficacy will vary across different types of activities and under different circumstances (Bandura, 1997). The theory specifies four sources of self-efficacy, including mastery, social modeling, social persuasion, and the physiological and affective feedback system. Mastery contributes to self-efficacy through successes or failures (Bandura, 1997). Success will enhance an individual's personal efficacy, while failure will lower it. The next source, social modeling, occurs as one compares their abilities to those of others (Bandura, 1997). Seeing people similar to oneself successfully perform a task will raise one's self-efficacy. Social persuasion will enhance self-efficacy if others express belief in one's abilities (Bandura, 1997). Physiological and affective feedback influences self-efficacy, especially in areas of physical accomplishments and health functioning (Bandura, 1997). For example, if an individual becomes fatigued, short of breath, or experiences pain while performing a physical activity, self-efficacy for the activity may be reduced. These four sources of self-efficacy provide significant opportunity for intervention and can be targeted to improve an individual's self-efficacy for a specific activity.

The proposed intervention in Paper 3 of this dissertation is based on the construct of self-efficacy from Social Cognitive Theory. The intervention has been modified from a previously successful exercise-specific self-efficacy based intervention. The core of this intervention was developed with multiple randomized controlled trials, including studies with community-dwelling middle-aged adults and older adults with COPD. The first iteration of the intervention was tested to enhance exercise adherence in middle-aged adults (McAuley et al., 1994). The intervention included activities designed to enhance the four sources of self-efficacy. Mastery accomplishments were enhanced as subjects were given feedback from researchers regarding their progress in exercise activities. Social modeling was targeted by showing videotapes of similar individuals participating in and achieving success in exercise activities. Social persuasion involved creating "buddy groups" of participants to exercise together and provide support to one another. The final source, physiological and affective feedback, was addressed through educating participants about normal responses to exercise and reassuring them that certain responses are expected and should not cause concern. The results of this study showed the intervention was effective for promoting exercise adherence. Subjects in the intervention group had higher adherence to exercise sessions than those in the attention control group who did not receive the self-efficacy enhancing component (67% vs. 55%). At the end of the five-month program, intervention group subjects were walking more miles per month than control group subjects

(14.76 miles vs. 10.40 miles) and spending more minutes per month walking (192.25 minutes vs. 132.80).

The next iteration of the self-efficacy enhancing intervention was conducted in older adults with COPD to examine the intervention's effects on upper body strength, physical activity, and exercise adherence (Covey et al., 2012). The intervention was modeled after the previously described McAuley et al. study and utilized similar techniques for enhancing the four sources of self-efficacy for exercise, along with upper body strength training. The results of this study showed that the intervention was effective for increasing strength and time spent in light physical activity (Larson et al., 2014). Subjects receiving the self-efficacy intervention increased light physical activity by 20.68 minutes/day, while the two groups without the self-efficacy component decreased their light physical activity by 22.43 and 25.73 minutes/day. Based on these findings, an intervention (Active for Life) is currently being tested in a large randomized controlled trial for individuals with COPD with a focus on increasing light physical activity and decreasing sedentary behavior (1R01NR016093). This intervention utilizes the self-efficacy enhancing techniques of the earlier foundational studies, along with exercise sessions that include walking and circuit training. The intervention proposed to assisted living residents in Paper 3 of this dissertation utilizes the self-efficacy enhancing techniques that have been shown to be effective for promoting physical activity.

In summary, a theoretical foundation is very important in planning an intervention targeting physical activity behaviors. Self-efficacy is a modifiable construct that can be targeted using strategies to impact its four sources. Interventions utilizing strategies to enhance self-efficacy for physical activity have been successful in populations of older adults and adults with chronic illness, suggesting it will be an appropriate theoretical foundation for an intervention to decrease sedentary behavior and increase light physical activity of older adults in assisted living.

Gaps

There are several gaps in the literature related to sedentary behavior of older adults. This dissertation focused on addressing three specific gaps. First, sedentary behavior in oldest old adults has not been comprehensively characterized, including volume of sedentary time and factors influencing sedentary behavior. Paper 1 addressed this gap by conducting a systematic literature review. Second, thorough techniques for optimally processing sedentary behavior data from the ActiGraph device have not been established, particularly for older adults with chronic obstructive pulmonary disease. Paper 2 addressed this gap by comparing various ActiGraph processing techniques to sedentary time measured with the gold standard ActivPAL device. Third, there is a lack of theory-based interventions focused on decreasing sedentary behavior and increasing light physical activity of older adults who reside in assisted living. Paper 3 began to address this gap through a qualitative study conducted with assisted living residents to directly inform the development of a proposed intervention, Active for Life in Assisted Living. A study testing the feasibility and acceptability of the Active for Life in Assisted Living intervention was included in the original plan for this dissertation, but was not possible due to COVID-19.

References

2018 Physical Activity Guidelines Advisory Committee Scientific Report. (2018). *Washington, DC: U.S. Department of Health and Human Services*.

Abbatecola, A. M., Paolisso, G., & Sinclair, A. J. (2015). Treating diabetes mellitus in older and oldest old patients. *Current Pharmaceutical Design*, *21*(13), 1665-1671. https://doi.org/10.2174/1381612821666150130120747

Abbott, K. M., Bettger, J. P., Hampton, K. N., & Kohler, H. P. (2015). The feasibility of measuring social networks among older adults in assisted living and dementia special care units. *Dementia*, *14*(2), 199-219.

Aguilar-Farias, N., Brown, W. J., Olds, T. S., & Geeske Peeters, G. M. (2015). Validity of self-report methods for measuring sedentary behaviour in older adults. *Journal of science and medicine in sport*, *18*(6), 662-666. https://doi.org/10.1016/j.jsams.2014.08.004 [doi]

Aguilar-Farias, N., Brown, W. J., & Peeters, G. M. (2014). ActiGraph GT3X+ cut-points for identifying sedentary behaviour in older adults in free-living environments. *Journal of science and medicine in sport*, *17*(3), 293-299. https://doi.org/10.1016/j.jsams.2013.07.002 [doi]

Alvarez, K. J., Kirchner, S., Chu, S., Smith, S., Winnick-Baskin, W., & Mielenz, T. J. (2015). Falls reduction and exercise training in an assisted living population. *Journal of Aging Research*(957598).

Amagasa, S., Fukushima, N., Kikuchi, H., Takamiya, T., Oka, K., & Inoue, S. (2017). Light and sporadic physical activity overlooked by current guidelines makes older women more active than older men. *The international journal of behavioral nutrition and physical activity*, *14*(1), 59-017-0519-0516. https://doi.org/10.1186/s12966-017-0519-6 [doi]

Araujo, G. M. D., Pinto, R. Z., Azevedo, B. R., Silva, F. G., Damato, T. M., Grande, G. D., Christofaro, D. G. D., & Oliveira, C. B. (2021). Measurement Properties of the Sedentary Behavior Questionnaire in Patients with Chronic Nonspecific Low Back Pain. *PM&R*, *13*(3), 250-257. https://doi.org/10.1002/pmrj.12490

Arguello, D., Andersen, K., Morton, A., Freedson, P. S., Intille, S. S., & John, D. (2018). Validity of proximity sensor-based wear-time detection using the ActiGraph GT9X. *J Sports Sci*, *36*(13), 1502-1507. https://doi.org/10.1080/02640414.2017.1398891

Bandura, A. (1997). *Self-efficacy: The exercise of control* W. H. Freeman and Company.

Bårdstu, H. B., Andersen, V., Fimland, M. S., Aasdahl, L., Lohne-Seiler, H., & Saeterbakken, A. H. (2021). Physical Activity Level Following Resistance Training in Community-Dwelling Older Adults Receiving Home Care: Results from a Cluster-Randomized Controlled Trial. *Int J Environ Res Public Health*, *18*(13).

Barone Gibbs, B., Brach, J. S., Byard, T., Creasy, S., Davis, K. K., McCoy, S., Peluso, A., Rogers, R. J., Rupp, K., & Jakicic, J. M. (2017). Reducing sedentary behavior versus increasing moderate-to-vigorous intensity physical activity in older adults. *Journal of Aging & Health*, *29*(2), 247-267. https://doi.org/10.1177/0898264316635564

Beato, M., Dawson, N., Svien, L., & Wharton, T. (2018). Examining the effects of an Otago-based home exercise program on falls and fall risks in an assisted living facility. . *Journal of Geriatric Physical Therapy*, *42*(4).

Beauchamp, M. K., Lee, A., Ward, R. F., Harrison, S. M., Bain, P. A., Goldstein, R. S., Brooks, D., Bean, J. F., & Jette, A. M. (2017). Do exercise interventions improve participation in life roles in older adults? A systematic review and meta-analysis. *Physical Therapy*, *97*(10), 964-974. https://doi.org/10.1093/ptj/pzx082

Bellettiere, J., LaMonte, M. J., Evenson, K. R., Rillamas-Sun, E., Kerr, J., Lee, I. M., Di, C., Rosenberg, D. E., Stefanick, M. L., Buchner, D. M., Hovell, M. F., & LaCroix, A. Z. (2019). Sedentary behavior and cardiovascular disease in older women: The OPACH study. *Circulation*, *139*(8), 1036-1046. https://doi.org/10.1161/CIRCULATIONAHA.118.035312

Bender, A. A., Halpin, S. N., Kemp, C. L., & Perkins, M. M. (2021). Barriers and Facilitators to Exercise Participation Among Frail Older African American Assisted Living Residents. *J Appl Gerontol*, *40*(3), 268-277.

Biswas, A., Oh, P. I., Faulkner, G. E., Bajaj, R. R., Silver, M. A., Mitchell, M. S., & Alter, D. A. (2015). Sedentary time and its association with risk for disease incidence, mortality, and hospitalization in adults: a systematic review and meta-analysis. *Annals of Internal Medicine*, *162*(2), 123-132. https://doi.org/10.7326/M14-1651 [doi]

Bonn, S. E., Bergman, P., Trolle Lagerros, Y., Sjölander, A., & Bälter, K. (2015). A Validation Study of the Web-Based Physical Activity Questionnaire Active-Q Against the GENEA Accelerometer. *JMIR Res Protoc*, *4*(3), e86. https://doi.org/10.2196/resprot.3896

Britten, L., Addington, C., & Astill, S. (2017). Dancing in time: feasibility and acceptability of a contemporary dance programme to modify risk factors for falling in community dwelling older adults. *BMC Geriatr*, *17*(1), 83. https://doi.org/10.1186/s12877-017-0476-6

Burke, L., Lee, A. H., Jancey, J., Xiang, L., Kerr, D. A., Howat, P. A., Hills, A. P., & Anderson, A. S. (2013). Physical activity and nutrition behavioural outcomes of a home-based intervention program for seniors: a randomized controlled trial. *Int J Behav Nutr Phys Act*, *10*, 14. https://doi.org/10.1186/1479-5868-10-14

Burton, E., Farrier, K., Galvin, R., Johnson, S., Horgan, N. F., Warters, A., & Hill, K. D. (2019). Physical activity programs for older people in the community receiving home care services: systematic review and meta-analysis. *Clin Interv Aging*, *14*, 1045-1064.

Burton, E., Farrier, K., Hill, K. D., Codde, J., Airey, P., & Hill, A.-M. (2017). Effectiveness of peers in delivering programs or motivating older people to increase their participation in physical activity: Systematic review and meta-analysis. *Journal of sports sciences*, *36*(6), 666-678. https://doi.org/10.1080/02640414.2017.1329549

Buttorff, C. R., Teague; Bauman, Melissa. (2017). *Multiple chronic conditions in the United States*.

Carlson, J. A., Tuz-Zahra, F., Bellettiere, J., Ridgers, N. D., Steel, C., Bejarano, C., LaCroix, A. Z., Rosenberg, D. E., Greenwood-Hickman, M. A., Jankowska, M. M., & Natarajan, L. (2021). Validity of Two Awake Wear-Time Classification Algorithms for activPAL in Youth, Adults, and Older Adults. *J Meas Phys Behav*, *4*(2), 151-162. https://doi.org/10.1123/jmpb.2020-0045

Carr, L. J., & Mahar, M. T. (2012). Accuracy of intensity and inclinometer output of three activity monitors for identification of sedentary behavior and light-intensity activity. *J Obes*, *2012*, 460271. https://doi.org/10.1155/2012/460271

Chaabene, H., Prieske, O., Herz, M., Moran, J., Höhne, J., Kliegl, R., Ramirez-Campillo, R., Behm, D. G., Hortobágyi, T., & Granacher, U. (2021). Home-based exercise programmes improve physical fitness of healthy older adults: A PRISMA-compliant systematic review and meta-analysis with relevance for COVID-19. *Ageing Res Rev*, *67*, 101265. https://doi.org/10.1016/j.arr.2021.101265

Chang, A. K., Fritschi, C., & Kim, M. J. (2014). Sedentary behavior, physical activity, and psychological health of Korean older adults with hypertension: Effect of an empowerment intervention. *Obesity Reviews*, *15*, 905-919.

Chao, Y. Y., Scherer, Y. K., Wu, Y. W., Lucke, K. T., & Montgomery, C. A. (2013). The feasibility of an intervention combining self-efficacy theory and Wii Fit exergames in assisted living residents: A pilot study. *Geriatric nursing*, *34*, 377-382.

Chase, J.-A. D. (2013). Physical activity interventions among older adults: A literature review. *Research and theory for nursing practice*, *27*(1), 53-80. https://doi.org/10.1891/1541-6577.27.1.53

Chase, J.-A. D. (2015). Interventions to increase physical activity among older adults: A meta-analysis. *Gerontologist*, *55*(4), 706-718. https://doi.org/10.1093/geront/gnu090

Chase, J.-A. D., Phillips, L. J., & Brown, M. (2017). Physical activity intervention effects on physical function among community-dwelling older adults: A systematic review and meta-analysis. *Journal of Aging and Physical Activity*, *25*(1), 149-170. https://doi.org/10.1123/japa.2016-0040

Chase, J. D., Otmanowski, J., Rowland, S., & Cooper, P. S. (2020). A systematic review and meta-analysis of interventions to reduce sedentary behavior among older adults. *Transl Behav Med*, *10*(5), 1078-1085. https://doi.org/10.1093/tbm/ibz189

Chastin, S., Gardiner, P. A., Harvey, J. A., Leask, C. F., Jerez-Roig, J., Rosenberg, D., Ashe, M. C., Helbostad, J. L., & Skelton, D. A. (2021). Interventions for reducing sedentary behaviour in community-dwelling older adults. *Cochrane Database Syst Rev*, *6*(6), CD012784.

Chastin, S. F. M., Buck, C., Freiberger, E., Murphy, M., Brug, J., Cardon, G., O'Donoghue, G., Pigeot, I., & Oppert, J. M. (2015). Systematic literature review of determinants of sedentary behaviour in older adults: A DEDIPAC study. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 127. https://doi.org/10.1186/s12966-015-0292-3

Chen, K. Y., Rothney, M. P., & Brychta, R. J. (2007). Physical activity monitors: Do more sensors mean better precision? *Journal of diabetes science and technology*, *1*(5), 768-770. https://doi.org/10.1177/193229680700100523

Chen, T., Narazaki, K., Honda, T., Chen, S., Haeuchi, Y., Nofuji, Y. Y., Matsuo, E., & Kumagai, S. (2015). Tri-axial accelerometer-determined daily physical activity and sedentary behavior of suburban community-dwelling older Japanese adults. *Journal of Sports Science and Medicine*, *14*(3), 507-514. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84939168260&partnerID=40&md5=eb55cdc41467c5fd8c1e470de88ce938

Chen, Y., Ringdahl, D., Trelstad-Porter, R., & Gurvich, O. V. (2021). Feasibility of Implementing a Tai Chi Program in an Assisted Living Facility: Reducing Fall Risks and Improving Quality of Life. *J Clin Med*, *10*(6). https://doi.org/10.3390/jcm10061277

Chen, Y.-M. (2010). Perceived barriers to physical activity among older adults residing in long-term care institutions. *Journal of Clinical Nursing*, *19*(3-4), 432-439. https://doi.org/10.1111/j.1365-2702.2009.02990.x

Chen, Y.-M., Li, Y.-P., & Yen, M.-L. (2015). Gender differences in the predictors of physical activity among assisted living residents. *Journal of Nursing Scholarship*, *47*(3), 211-218. https://doi.org/10.1111/jnu.12132

Choi, L., Liu, Z., Matthews, C. E., & Buchowski, M. S. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Medicine and science in sports and exercise*, *43*(2), 357-364. https://doi.org/10.1249/MSS.0b013e3181ed61a3 [doi]

Chou, C.-H. B., Hwang, C.-L. M. S., & Wu, Y.-T. P. (2012). Effect of exercise on physical function, daily living activities, and quality ofl ife in the frail older adults: A meta-analysis. *Archives of Physical Medicine and Rehabilitation*, *93*(2), 237-244. https://doi.org/10.1016/j.apmr.2011.08.042

Chudyk, A. M., McAllister, M. M., Cheung, H. K., McKay, H. A., & Ashe, M. C. (2017). Are we missing the sitting? Agreement between accelerometer non-wear time validation methods used with older adults' data. *Cogent medicine*, *4*, 1313505. https://doi.org/10.1080/2331205X.2017.1313505 [doi]

Cleland, C., Ferguson, S., Ellis, G., & Hunter, R. F. (2018). Validity of the International Physical Activity Questionnaire (IPAQ) for assessing moderate-to-vigorous physical activity and sedentary behaviour of older adults in the United Kingdom. *BMC MEDICAL RESEARCH METHODOLOGY*, *18*(1), 176. https://doi.org/10.1186/s12874-018-0642-3

Compernolle, S., Cardon, G., van der Ploeg, H. P., Van Nassau, F., De Bourdeaudhuij, I., Jelsma, J. J., Brondeel, R., & Van Dyck, D. (2020). Engagement, Acceptability, Usability, and Preliminary Efficacy of a Self-Monitoring Mobile Health Intervention to Reduce Sedentary Behavior in Belgian Older Adults: Mixed Methods Study. *JMIR Mhealth Uhealth*, *8*(10), e18653. https://doi.org/10.2196/18653

Conn, V. S., Minor, M. A., Burks, K. J., Rantz, M. J., & Pomeroy, S. H. (2003). Integrative review of physical activity intervention research with aging adults. *Journal of the American Geriatrics Society*, *51*(8), 1159-1168. https://doi.org/10.1046/j.1532-5415.2003.51365.x

Copeland, J. L., Clarke, J., & Dogra, S. (2015). Objectively measured and self-reported sedentary time in older Canadians. *Preventive Medicine Reports*, *2*, 90-95. https://doi.org/10.1016/j.pmedr.2015.01.003

Covey, M. K., McAuley, E., Kapella, M. C., Collins, E. G., Alex, C. G., Berbaum, M. L., & Larson, J. L. (2012). Upper-body resistance training and self-efficacy enhancement in COPD. *Journal of pulmonary & respiratory medicine*, *Suppl 9*, 001-105X.S009-001. https://doi.org/10.4172/2161-105X.S9-001 [doi]

Crombie, K. M., Leitzelar, B. N., Almassi, N. E., Mahoney, J. E., & Koltyn, K. F. (2021). The Feasibility and Effectiveness of a Community-Based Intervention to Reduce Sedentary Behavior in Older Adults. *J Appl Gerontol*, 733464820987919. https://doi.org/10.1177/0733464820987919

de Labra, C., Guimaraes-Pinheiro, C., Maseda, A., Lorenzo, T., & Millan-Calenti, J. C. (2015). Effects of physical exercise interventions in frail older adults: a systematic review of randomized controlled trials. *BMC geriatrics*, *15*(1), 154. https://doi.org/10.1186/s12877-015-0155-4

de Vries, N. M., van Ravensberg, C. D., Hobbelen, J. S. M., Olde Rikkert, M. G. M., Staal, J. B., & Nijhuis-van der Sanden, M. W. G. (2012). Effects of physical exercise therapy on mobility, physical functioning, physical activity and quality of life in community-dwelling older adults with impaired mobility, physical disability and/or multi-morbidity: A meta-analysis. *Ageing Research Reviews*, *11*(1), 136-149. https://doi.org/10.1016/j.arr.2011.11.002

Devereux-Fitzgerald, A., Powell, R., Dewhurst, A., & French, D. P. (2016). The acceptability of physical activity interventions to older adults: A systematic review and meta-synthesis. *Social Science & Medicine*, *158*, 14-23. https://doi.org/10.1016/j.socscimed.2016.04.006

Di Lorito, C., Long, A., Byrne, A., Harwood, R. H., Gladman, J. R. F., Schneider, S., Logan, P., Bosco, A., & van der Wardt, V. (2021). Exercise interventions for older adults: A systematic review of meta-analyses. *J Sport Health Sci 10*(1), 29-47.

Dillon, K., & Prapavessis, H. (2020). REducing SEDENTary Behavior Among Mild to Moderate Cognitively Impaired Assisted Living Residents: A Pilot Randomized Controlled Trial (RESEDENT Study). *J Aging Phys Act*, *29*(1), 27-35. https://doi.org/10.1123/japa.2019-0440

Dogra, S., & Stathokostas, L. (2012). Sedentary behavior and physical activity are independent predictors of successful aging in middle-aged and older adults. *Journal of Aging Research*, *2012*, 190654. https://doi.org/10.1155/2012/190654 [doi]

Drazich, B. F., LaFave, S., Crane, B. M., Szanton, S. L., Carlson, M. C., Budhathoki, C., & Taylor, J. L. (2020). Exergames and Depressive Symptoms in Older Adults: A Systematic Review. *Games Health J*, *9*(5), 339-345. https://doi.org/10.1089/g4h.2019.0165

Edwardson, C. L., Winkler, E. A. H., Bodicoat, D. H., Yates, T., Davies, M. J., Dunstan, D. W., & Healy, G. N. (2017). Considerations when using the ActivPAL monitor in field-based research with adult populations. *Journal of Sport and Health Science*, *6*(2), 162-178. https://doi.org/10.1016/j.jshs.2016.02.002

Ensrud, K. E., Blackwell, T. L., Cauley, J. A., Dam, T.-T. L., Cawthon, P. M., Schousboe, J. T., Barrett-Connor, E., Stone, K. L., Bauer, D. C., Shikany, J. M., & Mackey, D. C. (2014). Objective measures of activity level and mortality in older men. *Journal of the American Geriatrics Society*, *62*(11), 2079-2087. https://doi.org/10.1111/jgs.13101

Evenson, K. R., Morland, K. B., Wen, F., & Scanlin, K. (2014). Physical activity and sedentary behavior among adults 60 years and older: New York City residents compared with a national sample. *Journal of Aging and Physical Activity*, *22*(4), 499-507. https://doi.org/10.1123/japa.2012-0345 [doi]

Fanning, J., Porter, G., Awick, E. A., WÃ³jcicki, T. R., Gothe, N. P., Roberts, S. A., Ehlers, D. K., Motl, R. W., & McAuley, E. (2016). Effects of a DVD-delivered exercise program on patterns of sedentary behavior in older adults: A randomized controlled trial. *Preventive Medicine Reports*, *3*, 238-243. https://doi.org/10.1016/j.pmedr.2016.03.005

Fitzsimons, C. F., Kirk, A., Baker, G., Michie, F., Kane, C., & Mutrie, N. (2013). Using an individualised consultation and activPAL feedback to reduce sedentary time in older Scottish adults: Results of a feasibility and pilot study. *Preventive medicine*, *57*(5), 718-720. https://doi.org/10.1016/j.ypmed.2013.07.017 [doi]

Fowles, J. R., O'Brien, M. W., Wojcik, W. R., d'Entremont, L., & Shields, C. A. (2017). A pilot study: Validity and reliability of the CSEP-PATH PASB-Q and a new leisure time physical activity questionnaire to assess physical activity and sedentary behaviours. *Appl Physiol Nutr Metab*, *42*(6), 677-680. https://doi.org/10.1139/apnm-2016-0412

French, D. P., Olander, E. K., Chisholm, A., & Mc Sharry, J. (2014). Which behaviour change techniques are most effective at increasing older adults' self-efficacy and physical activity behaviour? A systematic review. *Annals of Behavioral Medicine*, *48*(2), 225-234. https://doi.org/10.1007/s12160-014-9593-z

Frost, R., Belk, C., Jovicic, A., Ricciardi, F., Kharicha, K., Gardner, B., Iliffe, S., Goodman, C., Manthorpe, J., Drennan, V. M., & Walters, K. (2017). Health promotion interventions for community-dwelling older people with mild or pre-frailty: a systematic review and meta-analysis. *BMC geriatrics*, *17*(1), 157. https://doi.org/10.1186/s12877-017-0547-8

Fuzeki, E., Engeroff, T., & Banzer, W. (2017). Health benefits of light-intensity physical activity: A systematic review of accelerometer data of the National Health and Nutrition Examination Survey (NHANES). *Sports medicine (Auckland, N.Z.)*, *47*(9), 1769-1793. https://doi.org/10.1007/s40279-017-0724-0 [doi]

Gammack, J. K. (2017). Physical Activity in Older Persons. *Mo Med*, *114*(2), 105-109.

Garcia-Aymerich, J., Lange, P., Benet, M., Schnohr, P., & Antó, J. M. (2006). Regular physical activity reduces hospital admission and mortality in chronic obstructive pulmonary disease: a population based cohort study. *Thorax*, *61*(9), 772-778. https://doi.org/10.1136/thx.2006.060145

Gardiner, P. A., Clark, B. K., Healy, G. N., Eakin, E. G., Winkler, E. A., & Owen, N. (2011). Measuring older adults' sedentary time: Reliability, validity, and responsiveness. *Medicine and science in sports and exercise*, *43*(11), 2127-2133. https://doi.org/10.1249/MSS.0b013e31821b94f7 [doi]

Gardiner, P. A., Eakin, E. G., Healy, G. N., & Owen, N. (2011). Feasibility of reducing older adults' sedentary time. *American Journal of Preventive Medicine*, *41*(2), 174-177. https://doi.org/10.1016/j.amepre.2011.03.020 [doi]

Gennuso, K. P., Matthews, C. E., & Colbert, L. H. (2015). Reliability and validity of two self-report measures to assess sedentary behavior in older adults. *Journal of physical activity & health*, *12*(5), 727-732. https://doi.org/10.1123/jpah.2013-0546 [doi]

Geraedts, H., Zijlstra, A., Bulstra, S. K., Stevens, M., & Zijlstra, W. (2013). Effects of remote feedback in home-based physical activity interventions for older adults: A systematic review. *Patient education and counseling*, *91*(1), 14-24. https://doi.org/10.1016/j.pec.2012.10.018

Giné-Garriga, M. P. P. T., Roqué-Fíguls, M. M. D., Coll-Planas, L. M. D., Sitjà-Rabert, M. P. P. T., & Salvà, A. M. D. (2014). Physical exercise interventions for improving performance-based measures of physical function in community-dwelling, frail older adults: A systematic review and meta-analysis. *Archives of Physical Medicine and Rehabilitation*, *95*(4), 753-769.e753. https://doi.org/10.1016/j.apmr.2013.11.007

Giuliani, C. A., Gruber-Baldini, A. L., Park, N. S., Schrodt, L. A., Rokoske, F., Sloane, P. D., & Zimmerman, S. (2008). Physical performance characteristics of assisted living residents and risk for adverse health outcomes. *Gerontologist*, *48*(2), 203-212. https://doi.org/10.1093/geront/48.2.203

Gourlan, M., Bernard, P., Bortolon, C., Romain, A. J., Lareyre, O., Carayol, M., Ninot, G., & Boiché, J. (2016). Efficacy of theory-based interventions to promote physical activity. A meta-analysis of randomised controlled trials. *Health Psychology Review*, *10*(1), 50-66. https://doi.org/10.1080/17437199.2014.981777

Grande, G. D., Oliveira, C. B., Morelhão, P. K., Sherrington, C., Tiedemann, A., Pinto, R. Z., & Franco, M. R. (2020). Interventions Promoting Physical Activity Among Older Adults: A Systematic Review and Meta-Analysis. *Gerontologist*, *60*(8), 583-599. https://doi.org/10.1093/geront/gnz167

Greene, C. M., Morgan, J. C., Traywick, L. S., & Mingo, C. A. (2017). Evaluation of a laughter-based exercise program on health and self-efficacy for exercise. *The Gerontologist*, *57*(6), 1051-1061.

Gregory, N., Gesell, S. B., & Widmer, T. (2007). Improving assisted living care. *Journal of Nursing Care Quality*, *22*(1), 50-58. https://doi.org/10.1097/00001786-200701000-00011

Gu, M. O., & Conn, V. S. (2008). Meta-analysis of the effects of exercise interventions on functional status in older adults. *Research in nursing & health*, *31*(6), 594-603. https://doi.org/10.1002/nur.20290

Harris-Kojetin, L., Sengupta, M., Lendon, J., Rome, V., Valverde, R., & Caffrey, C. (2019). Long-term care providers and services users in the United States, 2015–2016. *National Center for Health Statistics. Vital Health Stat*, *3*(43).

Harvey, J. A., Chastin, S. F., & Skelton, D. A. (2013). Prevalence of sedentary behavior in older adults: A systematic review. *International Journal of Environmental Research and Public Health*, *10*(12), 6645-6661. https://doi.org/10.3390/ijerph10126645 [doi]

Harvey, J. A., Chastin, S. F., & Skelton, D. A. (2015). How sedentary are older people? A systematic review of the amount of sedentary behavior. *Journal of Aging and Physical Activity*, *23*(3), 471-487. https://doi.org/10.1123/japa.2014-0164 [doi]

Healy, G. N., Clark, B. K., Winkler, E. A. H., Gardiner, P. A., Brown, W. J., & Matthews, C. E. (2011). Measurement of adults' sedentary time in population-based studies. *American*

Journal of Preventive Medicine, *41*(2), 216-227. https://doi.org/https://doi.org/10.1016/j.amepre.2011.05.005

Herbert, J. D., & Greene, D. (2001). Effect of preference on distance walked by assisted living residents. *Physical and Occupational Therapy in Geriatrics*, *19*(4), 1-15. https://doi.org/10.1300/J148v19v04_01

Hill, K. D., Hunter, S. W., Batchelor, F. A., Cavalheri, V., & Burton, E. (2015). Individualized home-based exercise programs for older people to reduce falls and improve physical performance: A systematic review and meta-analysis. *Maturitas*, *82*(1), 72-84. https://doi.org/10.1016/j.maturitas.2015.04.005

Hoffmann, C. M., Petrov, M. E., & Lee, R. E. (2021). Aerobic physical activity to improve memory and executive function in sedentary adults without cognitive impairment: A systematic review and meta-analysis. *Prev Med Rep*, *23*, 101496.

Holmes, S. D., Galik, E., & Resnick, B. (2017). Factors that influence physical activity among residents in assisted living. *Journal of gerontological social work*, *60*(2), 120-137. https://doi.org/10.1080/01634372.2016.1269035 [doi]

Houser, A., Fox-Grage, W., & Ujvari, K. (2018). *Across the States: Profiles of Long-Term Services and Supports*. A. P. P. Institute.

Hummer, D. B., Silva, S. G., Yap, T. L., Toles, M., & Anderson, R. A. (2015). Implementation of an exercise program in an assisted living facility. *Journal of Nursing Care Quality*, *30*(4), 373-379. https://doi.org/10.1097/NCQ.0000000000000125

Hyde, J., Perez, R., & Forester, B. (2007). Dementia and assisted living. *Gerontologist*, *47*(3).

Jefferis, B. J., Parsons, T. J., Sartini, C., Ash, S., Lennon, L. T., Papacosta, O., Morris, R. W., Wannamethee, S. G., Lee, I. M., & Whincup, P. H. (2018). Objectively measured physical activity, sedentary behaviour and all-cause mortality in older men: Does volume of activity matter more than pattern of accumulation? *British journal of sports medicine*, *53*(16). https://doi.org/10.1136/bjsports-2017-098733

John, D., Tyo, B., & Bassett, D. R. (2010). Comparison of four Actigraph accelerometers during walking and running. *Medicine and science in sports and exercise*, *42*(2), 368-374. https://doi.org/10.1249/MSS.0b013e3181b3af49

Johnson, J. A., McIlroy, W. E., Roy, E., Papaioannou, A., Thabane, L., & Giangregorio, L. (2013). Feasibility study of walking for exercise in individuals living in assisted living settings. *Journal of Geriatric Physical Therapy*, *36*(4), 175-181. https://doi.org/10.1519/JPT.0b013e318282d2d3

Kerr, J., Takemoto, M., Bolling, K., Atkin, A., Carlson, J., Rosenberg, D., Crist, K., Godbole, S., Lewars, B., Pena, C., & Merchant, G. (2016). Two-arm randomized pilot intervention trial to decrease sitting time and increase sit-to-stand transitions in working and non-working older adults. *PLoS ONE*, *11*(1), e0145427. https://doi.org/10.1371/journal.pone.0145427 [doi]

Kim, Y., Barry, V. W., & Kang, M. (2015). Validation of the ActiGraph GT3X and activPAL accelerometers for the assessment of sedentary behavior. *Measurement in Physical Education and Exercise Science*, *19*(3), 125-137. https://doi.org/10.1080/1091367X.2015.1054390

Klempel, N., Blackburn, N. E., McMullan, I. L., Wilson, J. J., Smith, L., Cunningham, C., O'Sullivan, R., Caserotti, P., & Tully, M. A. (2021). The Effect of Chair-Based Exercise on Physical Function in Older Adults: A Systematic Review and Meta-Analysis. *Int J Environ Res Public Health*, *18*(4).

Kluge, M. A., LeCompte, M., & Ramel, L. (2014). "Fit and fabulous": Mixed-methods research on processes, perceptions, and outcomes of a yearlong gym program with assisted-living residents. *Journal of Aging and Physical Activity*, *22*, 212-225.

Knott, S., Hollis, A., Jimenez, D., Dawson, N., Mabbagu, E., & Beato, M. (2021). Efficacy of Traditional Physical Therapy Versus Otago-Based Exercise in Fall Prevention for ALF-Residing Older Adults. *J Geriatr Phys Ther*. https://doi.org/10.1519/jpt.0000000000000285

Koltyn, K. F., Crombie, K. M., Brellenthin, A. G., Leitzelar, B., Ellingson, L. D., Renken, J., & Mahoney, J. E. (2019). Intervening to reduce sedentary behavior in older adults - pilot results. *Health Promot Perspect*, *9*(1), 71-76. https://doi.org/10.15171/hpp.2019.09

Koolhaas, C. M., van Rooij, F. J. A., Schoufour, J. D., Cepeda, M., Tiemeier, H., Brage, S., & Franco, O. H. (2017). Objective measures of activity in the elderly: Distribution and associations with demographic and health factors. *Journal of the American Medical Directors Association*, *18*(10), 838-847. https://doi.org/S1525-8610(17)30240-2 [pii]

Koster, A., Shiroma, E. J., Caserotti, P., Matthews, C. E., Chen, K. Y., Glynn, N. W., & Harris, T. B. (2016). Comparison of sedentary estimates between ActivPAL and hip- and wrist-worn ActiGraph. *Medicine and science in sports and exercise*, *48*(8), 1514-1522. https://doi.org/10.1249/MSS.0000000000000924 [doi]

Kotlarczyk, M. P., Hergenroeder, A. L., Gibbs, B. B., Cameron, F. A., Hamm, M. E., & Brach, J. S. (2020). Personal and Environmental Contributors to Sedentary Behavior of Older Adults in Independent and Assisted Living Facilities. *Int J Environ Res Public Health*, *17*(17).

Kozey-Keadle, S., Libertine, A., Lyden, K., Staudenmayer, J., & Freedson, P. S. (2011). Validation of wearable monitors for assessing sedentary behavior. *Medicine and science in sports and exercise*, *43*(8), 1561-1567. https://doi.org/10.1249/MSS.0b013e31820ce174 [doi]

Kumar, A., Delbaere, K., Zijlstra, G. A. R., Carpenter, H., Iliffe, S., Masud, T., Skelton, D., Morris, R., & Kenick, D. (2016). Exercise for reducing fear of falling in older people living in the community: Cochrane systematic review and meta-analysis. *Age and Ageing*, *45*(3), 345-352. https://doi.org/10.1093/ageing/afw036

Lacroix, A., Hortobágyi, T., Beurskens, R., & Granacher, U. (2017). Effects of supervised vs. unsupervised training programs on balance and muscle strength in older adults: A systematic review and meta-analysis. *Sports Medicine*, *47*(11), 2341-2361. https://doi.org/10.1007/s40279-017-0747-6

Larsen, L. H., Schou, L., Lund, H. H., & Langberg, H. (2013). The physical effect of exergames in healthy elderly-a systematic review. *Games for Health Journal*, *2*(4), 205-212.

Larsen, R. T., Christensen, J., Juhl, C. B., Andersen, H. B., & Langberg, H. (2019). Physical activity monitors to enhance amount of physical activity in older adults - a systematic review and meta-analysis. *Eur Rev Aging Phys Act*, *16*, 7.

Larson, J. L., Covey, M. K., Kapella, M. C., Alex, C. G., & McAuley, E. (2014). Self-efficacy enhancing intervention increases light physical activity in people with chronic obstructive pulmonary disease. *International journal of chronic obstructive pulmonary disease*, *9*, 1081-1090. https://doi.org/10.2147/COPD.S66846 [doi]

Lauze, M., Martel, D. D., & Aubertin-Leheudre, M. (2017). Feasibility and effects of a physical activity program using gerontechnology in assisted living communities for older adults. *Journal of the American Medical Directors Association*, *18*(12), 1069-1075. https://doi.org/S1525-8610(17)30373-0 [pii]

Leitzmann, M., Jochem, C., & Schmid, D. (2018). *Sedentary Behavior Epidemiology*. Springer International Publishing.

Leung, K. W., Sum, K. R., & Yang, Y. J. (2021). Patterns of Sedentary Behavior among Older Adults in Care Facilities: A Scoping Review. *Int J Environ Res Public Health*, *18*(5).

Leung, P. M., Ejupi, A., van Schooten, K. S., Aziz, O., Feldman, F., Mackey, D. C., Ashe, M. C., & Robinovitch, S. N. (2017). Association between Sedentary Behaviour and Physical, Cognitive, and Psychosocial Status among Older Adults in Assisted Living. *Biomed Res Int*, *2017*, 9160504.

Lewis, L. K., Rowlands, A. V., Gardiner, P. A., Standage, M., English, C., & Olds, T. (2016). Small Steps: Preliminary effectiveness and feasibility of an incremental goal-setting intervention to reduce sitting time in older adults. *Maturitas*, *85*, 64-70. https://doi.org/10.1016/j.maturitas.2015.12.014 [doi]

Liberman, K., Forti, L. N., Beyer, I., & Bautmans, I. (2017). The effects of exercise on muscle strength, body composition, physical functioning and the inflammatory profile of older adults: A systematic review. *Current Opinion in Clinical Nutrition and Metabolic Care*, *20*(1), 30-53. https://doi.org/10.1097/MCO.0000000000000335

Lopopolo, R. B., Greco, M., Sullivan, D., Craik, R. L., & Mangione, K. K. (2006). Effect of therapeutic exercise on gait speed in community-dwelling elderly people: A meta-analysis. *Physical Therapy*, *86*(4), 520-540. https://doi.org/10.1093/ptj/86.4.520

Lu, Z. (2010). Investigating walking environments in and around assisted living facilities: A facility visit study. *HERD: Health Environments Research & Design Journal*, *3*(4), 58-74. https://doi.org/10.1177/193758671000300406

Lyons, E. J., Swartz, M. C., Lewis, Z. H., Martinez, E., & Jennings, K. (2017). Feasibility and Acceptability of a Wearable Technology Physical Activity Intervention With Telephone Counseling for Mid-Aged and Older Adults: A Randomized Controlled Pilot Trial. *JMIR Mhealth Uhealth*, *5*(3), e28. https://doi.org/10.2196/mhealth.6967

Maher, J. P., Sliwinski, M. J., & Conroy, D. E. (2017). Feasibility and preliminary efficacy of an intervention to reduce older adults' sedentary behavior. *Translational Behavioral Medicine*, *1*, 52-61.

Mahrs Träff, A., Cedersund, E., & Nord, C. (2017). Perceptions of physical activity among elderly residents and professionals in assisted living facilities. *European Review of Aging and Physical Activity*, *14*(1). https://doi.org/10.1186/s11556-017-0171-9

Matei, R., Thune-Boyle, I., Hamer, M., Iliffe, S., Fox, K. R., Jefferis, B. J., & Gardner, B. (2015). Acceptability of a theory-based sedentary behaviour reduction intervention for older adults ('On Your Feet to Earn Your Seat'). *BMC Public Health*, *15*, 606-015-1921-1920. https://doi.org/10.1186/s12889-015-1921-0 [doi]

Matson, T. E., Renz, A. D., Takemoto, M. L., McClure, J. B., & Rosenberg, D. E. (2018). Acceptability of a sitting reduction intervention for older adults with obesity. *BMC Public Health*, *18*(1), 706-018-5616-5611. https://doi.org/10.1186/s12889-018-5616-1 [doi]

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R., & Troiano, R. P. (2008). Amount of time spent in sedentary behaviors in the United States, 2003-2004. *American Journal of Epidemiology*, *167*(7), 875-881. https://doi.org/10.1093/aje/kwm390 [doi]

McAuley, E., Courneya, K. S., Rudolph, D. L., & Lox, C. L. (1994). Enhancing exercise adherence in middle-aged males and females. *Preventive medicine*, *23*(4), 498-506. https://doi.org/S0091-7435(84)71068-1 [pii]

McAuley, E., Mailey, E. L., Mullen, S. P., Szabo, A. N., Wojcicki, T. R., White, S. M., Gothe, N., Olson, E. A., & Kramer, A. F. (2011). Growth trajectories of exercise self-efficacy in older adults: Influence of measures and initial status. *Health psychology : official journal* *of the Division of Health Psychology, American Psychological Association*, *30*(1), 75-83. https://doi.org/10.1037/a0021567 [doi]

Mihalko, S. L., & Wickley, K. L. (2003). Active living for assisted living: Promoting partnerships within a systems framework. *American Journal of Preventive Medicine*, *25*(3 Suppl 2), 193-203. https://doi.org/S0749379703001843 [pii]

Miller, K. J., Areerob, P., Hennessy, D., Gonçalves-Bradley, D. C., Mesagno, C., & Grace, F. (2020). Aerobic, resistance, and mind-body exercise are equivalent to mitigate symptoms of depression in older adults: A systematic review and network meta-analysis of randomised controlled trials. *F1000Res*, *9*, 1325. https://doi.org/10.12688/f1000research.27123.2

Mollica, R., Houser, A., & Ujvari, K. (2012). *Assisted living and residential care in the states in 2010*. A. P. P. Institute.

Montoye, A. H. K., Nelson, M. B., Bock, J. M., Imboden, M. T., Kaminsky, L. A., Mackintosh, K. A., McNarry, M. A., & Pfeiffer, K. A. (2018). Raw and Count Data Comparability of Hip-Worn ActiGraph GT3X+ and Link Accelerometers. *Medicine & Science in Sports & Exercise*, *50*(5), 1103-1112. https://doi.org/10.1249/MSS.0000000000001534

Moore, M., Warburton, J., O'Halloran, P. D., Shields, N., & Kingsley, M. (2016). Effective community-based physical activity interventions for older adults living in rural and regional areas: A systematic review. *Journal of Aging and Physical Activity*, *24*(1), 158-167. https://doi.org/10.1123/japa.2014-0218

Moran, F., MacMillan, F., Smith-Merry, J., Kilbreath, S., & Merom, D. (2015). Perceived barriers, facilitators and patterns of physical activity of older-old adults living in assisted retirement accommodation : A qualitative and quantitative pilot research. *Gerontology & Geriatric Research*, *4*(6).

Muellmann, S., Forberger, S., Möllers, T., Bröring, E., Zeeb, H., & Pischke, C. R. (2018). Effectiveness of eHealth interventions for the promotion of physical activity in older adults: A systematic review. *Prev Med*, *108*, 93-110. https://doi.org/10.1016/j.ypmed.2017.12.026

Müller, A. M., Khoo, S., & Morris, T. (2016). Text Messaging for Exercise Promotion in Older Adults From an Upper-Middle-Income Country: Randomized Controlled Trial. *J Med Internet Res*, *18*(1), e5. https://doi.org/10.2196/jmir.5235

Mutrie, N., Doolin, O., Fitzsimons, C. F., Grant, P. M., Granat, M., Grealy, M., Macdonald, H., MacMillan, F., McConnachie, A., Rowe, D. A., Shaw, R., & Skelton, D. A. (2012). Increasing older adults' walking through primary care: results of a pilot randomized controlled trial. *Fam Pract*, *29*(6), 633-642. https://doi.org/10.1093/fampra/cms038

Naber, A., Lucas Molitor, W., Farriell, A., Honius, K., & Poppe, B. (2020). The Exploration of Occupational Therapy Interventions to Address Sedentary Behavior and Pain Among Older Adults [Journal Article]. *Journal of Aging and Physical Activity*, *28*(3), 391-398. http://proxy.lib.umich.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=gnh&AN=EP143368926&site=ehost-live&scope=site

Naylor, E., Penev, P. D., Orbeta, L., Janssen, I., Ortiz, R., Colecchia, E. F., Keng, M., Finkel, S., & Zee, P. C. (2000). Daily social and physical activity increases slow-wave sleep and daytime neuropsychological performance in the elderly. *Sleep*, *23*(1), 87-95.

Okubo, Y., Schoene, D., & Lord, S. R. (2017). Step training improves reaction time, gait and balance and reduces falls in older people: A systematic review and meta-analysis. *British journal of sports medicine*, *51*(7), 586-586. https://doi.org/10.1136/bjsports-2015-095452

Olanrewaju, O., Kelly, S., Cowan, A., Brayne, C., & Lafortune, L. (2016). Physical activity in community dwelling older people: A systematic review of reviews of interventions and context. *PLoS ONE*, *11*(12), e0168614. https://doi.org/10.1371/journal.pone.0168614

Oliveira, J. S., Sherrington, C., Amorim, A. B., Dario, A. B., & Tiedemann, A. (2017). What is the effect of health coaching on physical activity participation in people aged 60 years and over? A systematic review of randomised controlled trials. *British journal of sports medicine*, *51*(19), 1425-U1468. https://doi.org/10.1136/bjsports-2016-096943

Owari, Y., Suzuki, H., & Miyatake, N. (2019). "Active Guide" Brochure Reduces Sedentary Behavior of Elderly People: A Randomized Controlled Trial. *Acta Med Okayama*, *73*(5), 427-432. https://doi.org/10.18926/amo/57373

Owen, N., Sparling, P. B., Healy, G. N., Dunstan, D. W., & Matthews, C. E. (2010). Sedentary behavior: Emerging evidence for a new health risk. *Mayo Clinic proceedings*, *85*(12), 1138-1141. https://doi.org/10.4065/mcp.2010.0444 [doi]

Park, J. H., Moon, J. H., Kim, H. J., Kong, M. H., & Oh, Y. H. (2020). Sedentary Lifestyle: Overview of Updated Evidence of Potential Health Risks. *Korean J Fam Med*, *41*(6), 365-373.

Park, S., Thøgersen-Ntoumani, C., Ntoumanis, N., Stenling, A., Fenton, S. A. M., & Veldhuijzen, v. Z. (2017). Profiles of Physical Function, Physical Activity, and Sedentary Behavior and their Associations with Mental Health in Residents of Assisted Living Facilities. *Applied Psychology: Health and Well-Being*, *9*(1), 60-80. https://doi.org/10.1111/aphw.12085

Petrusevski, C., Choo, S., Wilson, M., MacDermid, J., & Richardson, J. (2020). Interventions to address sedentary behaviour for older adults: a scoping review. *Disabil Rehabil*, 1-12. https://doi.org/10.1080/09638288.2020.1725156

Pfister, T., Matthews, C. E., Wang, Q., Kopciuk, K. A., Courneya, K., & Friedenreich, C. (2017). A comparison of two accelerometers for measuring physical activity and sedentary behaviour. *BMJ Open Sport & Exercise Medicine 3*.

Phillips, L. J., & Flesner, M. (2013). Perspectives and experiences related to physical activity of elders in long-term-care settings. *J Aging Phys Act*, *21*(1), 33-50. https://doi.org/10.1123/japa.21.1.33

Phillips, L. J., Leary, E., Blankenship, J., & Zimmerman, S. (2017). Physical function, relocation, and mortality outcomes in residential care and assisted living residents. *Journal of aging and health*, 89826431774004. https://doi.org/10.1177/0898264317740047

Phillips, L. J., Petroski, G. F., Conn, V. S., Brown, M., Leary, E., Teri, L., & Zimmerman, S. (2018). Exploring Path Models of Disablement in Residential Care and Assisted Living Residents. *J Appl Gerontol*, *37*(12), 1490-1516.

Physical activity guidelines for Americans, 2nd edition. (2018).

Picorelli, A. M. A., Pereira, L. S. M., Pereira, D. S., Felício, D., & Sherrington, C. (2014). Adherence to exercise programs for older people is influenced by program characteristics and personal factors: A systematic review. *Journal of physiotherapy*, *60*(3), 151-156. https://doi.org/10.1016/j.jphys.2014.06.012

Pinheiro, M. B., Oliveira, J., Bauman, A., Fairhall, N., Kwok, W., & Sherrington, C. (2020). Evidence on physical activity and osteoporosis prevention for people aged 65+ years: a systematic review to inform the WHO guidelines on physical activity and sedentary behaviour. *Int J Behav Nutr Phys Act*, *17*(1), 150.

Plotnikoff, R. C., Costigan, S. A., Short, C., Grunseit, A., James, E., Johnson, N., Bauman, A., D'Este, C., van der Ploeg, H. P., & Rhodes, R. E. (2015). Factors associated with higher sitting time in general, chronic disease, and psychologically-distressed, adult populations: Findings from the 45 & Up Study. *PLoS ONE*, *10*(6), e0127689. https://doi.org/10.1371/journal.pone.0127689

Plummer, P., Zukowski, L. A., Giuliani, C., Hall, A. M., & Zurakowski, D. (2015). Effects of physical exercise interventions on gait-related dual-task interference in older adults: A systematic review and meta-analysis. *Gerontology*, *62*(1), 94-117. https://doi.org/10.1159/000371577

Plys, E., & Qualls, S. H. (2020). Sense of community and its relationship with psychological well-being in assisted living. *Aging Ment Health*, *24*(10), 1645-1653. https://doi.org/10.1080/13607863.2019.1647133

Posey, M. L. (2017). *Trends in the behavioral and social sciences*

Reid, N., Eakin, E., Henwood, T., Keogh, J. W. L., Senior, H. E., Gardiner, P. A., Winkler, E., & Healy, G. N. (2013). Objectively measured activity patterns among adults in residential aged care. *International Journal of Environmental Research and Public Health*, *10*(12), 6783-6798. https://doi.org/10.3390/ijerph10126783

Resnick, B., Boltz, M., Galik, E., Fix, S., Holmes, S., Zhu, S., & Barr, E. (2021). Testing the Implementation of Function-focused Care in Assisted Living Settings. *J Am Med Dir Assoc*, *22*(8), 1706-1713.e1701. https://doi.org/10.1016/j.jamda.2020.09.026

Resnick, B., Boltz, M., Galik, E., & Zhu, S. (2021). The Impact of a Randomized Controlled Trial Testing the Implementation of Function-Focused Care in Assisted Living on Resident Falls, Hospitalizations, and Nursing Home Transfers. *J Aging Phys Act*, 1-9. https://doi.org/10.1123/japa.2020-0426

Resnick, B., Galik, E., Gruber-Baldini, A., & Zimmerman, S. (2011). Testing the effect of function-focused care in assisted living. *Journal of the American Geriatrics Society*, *59*(12), 2233-2240. https://doi.org/10.1111/j.1532-5415.2011.03699.x [doi]

Resnick, B., Galik, E., Gruber-Baldini, A. L., & Zimmerman, S. (2009). Implementing a restorative care philosophy of care in assisted living: Pilot testing of Res-Care-AL. *Journal of the American Academy of Nurse Practitioners*, *21*(2), 123-133. https://doi.org/10.1111/j.1745-7599.2008.00394.x [doi]

Resnick, B., Galik, E., Vigne, E., & Carew, A. P. (2016). Dissemination and implementation of function focused care for assisted living. *Health Education & Behavior*, *43*(3), 296-304. https://doi.org/10.1177/1090198115599984

Roberts, C. E., Phillips, L. H., Cooper, C. L., Gray, S., & Allan, J. L. (2017). Effect of different types of physical activity on activities of daily living in older adults: Systematic review and meta-analysis. *Journal of Aging and Physical Activity*, *25*(4), 653-670. https://doi.org/10.1123/japa.2016-0201

Roberts, L. M., Jaeger, B. C., Baptista, L. C., Harper, S. A., Gardner, A. K., Jackson, E. A., Pekmezi, D., Sandesara, B., Manini, T. M., Anton, S. D., & Buford, T. W. (2019). Wearable Technology To Reduce Sedentary Behavior And CVD Risk In Older Adults: A Pilot Randomized Clinical Trial. *Clin Interv Aging*, *14*, 1817-1828. https://doi.org/10.2147/cia.S222655

Robinson, K. R., Masud, T., & Hawley-Hague, H. (2016). Instructors' Perceptions of Mostly Seated Exercise Classes: Exploring the Concept of Chair Based Exercise. *Biomed Res Int*, *2016*, 3241873.

Rooijackers, T. H., Kempen, G., Zijlstra, G. A. R., van Rossum, E., Koster, A., Lima Passos, V., & Metzelthin, S. F. (2021). Effectiveness of a reablement training program for homecare staff on older adults' sedentary behavior: A cluster randomized controlled trial. *J Am Geriatr Soc*, *69*(9), 2566-2578. https://doi.org/10.1111/jgs.17286

Rosenberg, D. E., Anderson, M. L., Renz, A., Matson, T. E., Lee, A. K., Greenwood-Hickman, M. A., Arterburn, D. E., Gardiner, P. A., Kerr, J., & McClure, J. B. (2020). Reducing Sitting Time in Obese Older Adults: The I-STAND Randomized Controlled Trial. *J Aging Phys Act*, 1-11. https://doi.org/10.1123/japa.2019-0470

Rosenberg, D. E., Gell, N. M., Jones, S. M., Renz, A., Kerr, J., Gardiner, P. A., & Arterburn, D. (2015). The feasibility of reducing sitting time in overweight and obese older adults. *Health education & behavior 42*(5), 669-676. https://doi.org/10.1177/1090198115577378 [doi]

Rosenberg, D. E., Kadokura, E., Morris, M. E., Renz, A., & Vilardaga, R. M. (2017). Application of N-of-1 experiments to test the efficacy of inactivity alert features in fitness trackers to increase breaks from sitting in older adults. *Methods of Information in Medicine*, *56*(6), 427-436. https://doi.org/10.3414/ME16-02-0043

Rosenberg, D. E., Norman, G. J., Wagner, N., Patrick, K., Calfas, K. J., & Sallis, J. F. (2010). Reliability and validity of the Sedentary Behavior Questionnaire (SBQ) for adults. *J Phys Act Health*, *7*(6), 697-705. https://doi.org/10.1123/jpah.7.6.697

Rothman, A. J. (2004). "Is there nothing more practical than a good theory?": Why innovations and advances in health behavior change will arise if interventions are used to test and refine theory. *International Journal of Behavioral Nutrition and Physical Activity*, *1*(1), 11-11. https://doi.org/10.1186/1479-5868-1-11

Ryan, D. J., Wullems, J. A., Stebbings, G. K., Morse, C. I., Stewart, C. E., & Onambele-Pearson, G. L. (2018). Reliability and validity of the international physical activity questionnaire compared to calibrated accelerometer cut-off points in the quantification of sedentary behaviour and physical activity in older adults. *PLoS ONE*, *13*(4). https://doi.org/10.1371/journal.pone.0195712

Sansano-Nadal, O., Giné-Garriga, M., Brach, J. S., Wert, D. M., Jerez-Roig, J., Guerra-Balic, M., Oviedo, G., Fortuño, J., Gómara-Toldrà, N., Soto-Bagaria, L., Pérez, L. M., Inzitari, M., Solà, I., Martin-Borràs, C., & Roqué, M. (2019). Exercise-Based Interventions to Enhance Long-Term Sustainability of Physical Activity in Older Adults: A Systematic Review and Meta-Analysis of Randomized Clinical Trials. *Int J Environ Res Public Health*, *16*(14).

Sansano-Nadal, O., Wilson, J. J., Martín-Borràs, C., Brønd, J. C., Skjødt, M., Caserotti, P., Roqué I Figuls, M., Blackburn, N. E., Klenk, J., Rothenbacher, D., Guerra-Balic, M., Font-Farré, M., Denkinger, M., Coll-Planas, L., Deidda, M., McIntosh, E., Giné-Garriga, M., & Tully, M. A. (2021). Validity of the Sedentary Behavior Questionnaire in European Older Adults Using English, Spanish, German and Danish Versions. *Measurement in Physical Education and Exercise Science*, 1-14. https://doi.org/10.1080/1091367X.2021.1922910

Sartini, C., Wannamethee, S. G., Iliffe, S., Morris, R. W., Ash, S., Lennon, L., Whincup, P. H., & Jefferis, B. J. (2015). Diurnal patterns of objectively measured physical activity and sedentary behaviour in older men. *BMC Public Health*, *15*, 609-015-1976-y. https://doi.org/10.1186/s12889-015-1976-y [doi]

Schrack, J. A., Leroux, A., Fleg, J. L., Zipunnikov, V., Simonsick, E. M., Studenski, S. A., Crainiceanu, C., & Ferrucci, L. (2018). Using heart rate and accelerometry to define quantity and intensity of physical activity in older adults. *Journals of Gerontology - Series A Biological Sciences and Medical Sciences*, *73*(5), 668-675. https://doi.org/10.1093/gerona/gly029

Sherrington, C., Fairhall, N., Kwok, W., Wallbank, G., Tiedemann, A., Michaleff, Z. A., Ng, C., & Bauman, A. (2020). Evidence on physical activity and falls prevention for people aged 65+ years: systematic review to inform the WHO guidelines on physical activity and sedentary behaviour. *Int J Behav Nutr Phys Act*, *17*(1), 144.

Shiroma, E. J., Freedson, P. S., Trost, S. G., & Lee, I. M. (2013). Patterns of accelerometer-assessed sedentary behavior in older women. *Jama*, *310*(23), 2562-2563. https://doi.org/10.1001/jama.2013.278896 [doi]

Sparling, P. B., Howard, B. J., Dunstan, D. W., & Owen, N. (2015). Recommendations for physical activity in older adults. *BMJ (Clinical research ed.)*, *350*, h100. https://doi.org/10.1136/bmj.h100 [doi]

Stanmore, E. K., Mavroeidi, A., de Jong, L. D., Skelton, D. A., Sutton, C. J., Benedetto, V., Munford, L. A., Meekes, W., Bell, V., & Todd, C. (2019). The effectiveness and cost-effectiveness of strength and balance Exergames to reduce falls risk for people aged 55 years and older in UK assisted living facilities: A multi-centre, cluster randomised controlled trial. *BMC Med*, *17*(1), 49. https://doi.org/10.1186/s12916-019-1278-9

Stockwell, S., Schofield, P., Fisher, A., Firth, J., Jackson, S. E., Stubbs, B., & Smith, L. (2019). Digital behavior change interventions to promote physical activity and/or reduce sedentary behavior in older adults: A systematic review and meta-analysis. *Exp Gerontol*, *120*, 68-87. https://doi.org/10.1016/j.exger.2019.02.020

Street, D., Burge, S., Quadagno, J., & Barrett, A. (2007). The salience of social relationships for resident well-being in assisted living. *The journals of gerontology.Series B, Psychological sciences and social sciences*, *62*(2), S129-S134.

Suboc, T. B., Strath, S. J., Dharmashankar, K., Coulliard, A., Miller, N., Wang, J., Tanner, M. J., & Widlansky, M. E. (2014). Relative importance of step count, intensity, and duration on physical activity's impact on vascular structure and function in previously sedentary older adults. *J Am Heart Assoc*, *3*(1), e000702. https://doi.org/10.1161/jaha.113.000702

Sung, K. (2009). The effects of 16-week group exercise program on physical function and mental health of elderly Korean women in long-term assisted living facility. *The Journal of cardiovascular nursing*, *24*(5), 344.

Swartz, A. M., Cho, C. C., Welch, W. A., Widlansky, M. E., Maeda, H., & Strath, S. J. (2018). Pattern analysis of sedentary behavior change after a walking intervention. *American Journal of Health Behavior*, *42*(3), 90-101. https://doi.org/10.5993/AJHB.42.3.9

Taylor, J., Walsh, S., Kwok, W., Pinheiro, M. B., de Oliveira, J. S., Hassett, L., Bauman, A., Bull, F., Tiedemann, A., & Sherrington, C. (2021). A scoping review of physical activity interventions for older adults. *Int J Behav Nutr Phys Act*, *18*(1), 82.

Taylor, L., Whittington, F., Hollingsworth, C., Ball, M., S., K., V., P., S., D., Rosenbloom, C., & Neel, A. (2003). Assessing the effectiveness of a walking program on physical function of residents living in an assisted living facility. *Journal of Community Health Nursing*, *20*(1), 15-26. https://doi.org/10.1207/153276503321159340

Thralls Butte, K., & Levy, S. S. (2020). Stand Up Now: A Sedentary Behavior Intervention in Older Adults of Moderate to Low Physical Function. *J Aging Phys Act*, *29*(3), 516-528. https://doi.org/10.1123/japa.2020-0047

Tosi, F. C., Lin, S. M., Gomes, G. C., Aprahamian, I., Nakagawa, N. K., Viveiro, L., Bacha, J. M. R., Jacob-Filho, W., & Pompeu, J. E. (2021). A multidimensional program including standing exercises, health education, and telephone support to reduce sedentary behavior in frail older adults: Randomized clinical trial. *Exp Gerontol*, *153*, 111472. https://doi.org/10.1016/j.exger.2021.111472

Toto, P. E., Raina, K. D., Holm, M. B., Schlenk, E. A., Rubinstein, E. N., & Rogers, J. C. (2012). Outcomes of a multicomponent physical activity program for sedentary, community-dwelling older adults. *J Aging Phys Act*, *20*(3), 363-378. https://doi.org/10.1123/japa.20.3.363

Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., Chastin, S. F. M., Altenburg, T. M., & Chinapaw, M. J. M. (2017). Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. *International Journal of Behavioral Nutrition and Physical Activity*, *14*(1), 1-17. https://doi.org/10.1186/s12966-017-0525-8

Tremblay, M. S., Colley, R. C., Saunders, T. J., Healy, G. N., & Owen, N. (2010). Physiological and health implications of a sedentary lifestyle. *Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme*, *35*(6), 725-740. https://doi.org/10.1139/H10-079 [doi]

Tryon, W. W., & Williams, R. (1996). Fully proportional actigraphy: A new instrument. *Behavior Research Methods, Instruments, and Computers*, *28*(3), 392-403. https://doi.org/10.3758/BF03200519

Tsai, L.-T., Rantakokko, M., Rantanen, T., Viljanen, A., Kauppinen, M., & Portegijs, E. (2016). Objectively measured physical activity and changes in life-space mobility among older people. *Journals of Gerontology Series A: Biological Sciences & Medical Sciences*, *71*(11), 1466-1471. http://proxy.lib.umich.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=ccm&AN=119757857&site=ehost-live&scope=site

Van Abbema, R., De Greef, M., Craje, C., Krijnen, W., Hobbelen, H., & van der Schans, C. (2015). What type, or combination of exercise can improve preferred gait speed in older adults? A meta-analysis. *BMC geriatrics*, *15*(1), 72. https://doi.org/10.1186/s12877-015-0061-9

Van Cauwenberg, J., Van Holle, V., De Bourdeaudhuij, I., Owen, N., & Deforche, B. (2014). Older adults' reporting of specific sedentary behaviors: validity and reliability. *BMC Public Health*, *14*, 734-2458-2414-2734. https://doi.org/10.1186/1471-2458-14-734 [doi]

van der Berg, J. D., Willems, P. J., van der Velde, J. H., Savelberg, H. H., Schaper, N. C., Schram, M. T., Sep, S. J., Dagnelie, P. C., Bosma, H., Stehouwer, C. D., & Koster, A. (2016). Identifying waking time in 24-h accelerometry data in adults using an automated algorithm. *Journal of sports sciences*, *34*(19), 1867-1873. https://doi.org/10.1080/02640414.2016.1140908 [doi]

Van Roie, E., Martien, S., Hurkmans, E., Pelssers, J., Seghers, J., Boen, F., & Delecluse, C. (2017). Ergometer-cycling with strict versus minimal contact supervision among the oldest adults: A cluster-randomised controlled trial. *Archives of Gerontology and Geriatrics*, *70*, 112-122. https://doi.org/10.1016/j.archger.2017.01.010

Vanderlinden, J., Boen, F., & van Uffelen, J. G. Z. (2020). Effects of physical activity programs on sleep outcomes in older adults: a systematic review. *Int J Behav Nutr Phys Act*, *17*(1), 11.

Vanroy, J., Seghers, J., van Uffelen, J., & Boen, F. (2019). Can a framed intervention motivate older adults in assisted living facilities to exercise? *BMC Geriatr*, *19*(1), 46. https://doi.org/10.1186/s12877-019-1060-z

Visser, M., & Koster, A. (2013). Development of a questionnaire to assess sedentary time in older persons - A comparative study using accelerometry. *BMC geriatrics*, *13*(1). https://doi.org/10.1186/1471-2318-13-80

Vorrink, S. N. W., Kort, H. S. M., Troosters, T., & Lammers, J. W. J. (2011). Level of daily physical activity in individuals with COPD compared with healthy controls. *Respiratory research*, *12*(1). https://doi.org/10.1186/1465-9921-12-33

Vos, C. (2017). Physical activity in assisted living facility residents.

Vos, C. M., Saint Arnault, D. M., Struble, L. M., Gallagher, N. A., & Larson, J. L. (2019). The Experience and Meaning of Physical Activity in Assisted Living Facility Residents. *J Aging Phys Act*, *27*(3), 406-412. https://doi.org/10.1123/japa.2018-0026

Voss, M. L., Pope, J. P., & Copeland, J. L. (2020). Reducing Sedentary Time among Older Adults in Assisted Living: Perceptions, Barriers, and Motivators. *International Journal of Environmental Research and Public Health*, *17*.

Voss, M. L., Pope, J. P., Larouche, R., & Copeland, J. L. (2020). Stand When You Can: Development and pilot testing of an intervention to reduce sedentary time in assisted living [Article]. *BMC geriatrics*, *20*(1), Article 277. https://doi.org/10.1186/s12877-020-01647-z

Wang, X., Breneman, C. B., Sparks, J. R., & Blair, S. N. (2020). Sedentary Time and Physical Activity in Older Women Undergoing Exercise Training. *Med Sci Sports Exerc*, *52*(12), 2590-2598. https://doi.org/10.1249/mss.0000000000002407

Washburn, R. A., Smith, K. W., Jette, A. M., & Janney, C. A. (1993). The physical activity scale for the elderly (PASE): Development and evaluation. *Journal of clinical epidemiology*, *46*(2), 153-162. https://doi.org/10.1016/0895-4356(93)90053-4

Weber, M., Belala, N., Clemson, L., Boulton, E., Hawley-Hague, H., Becker, C., & Schwenk, M. (2018). Feasibility and effectiveness of intervention programmes integrating functional exercise into daily life of older adults: A systematic review. *Gerontology*, *64*(2), 172-187. https://doi.org/10.1159/000479965

White, I., Smith, L., Aggio, D., Shankar, S., Begum, S., Matei, R., Fox, K. R., Hamer, M., Iliffe, S., Jefferis, B. J., Tyler, N., & Gardner, B. (2017). On Your Feet to Earn Your Seat: pilot RCT of a theory-based sedentary behaviour reduction intervention for older adults. *Pilot Feasibility Stud*, *3*, 23. https://doi.org/10.1186/s40814-017-0139-6

Williams, K. N., & Warren, C. A. B. (2008). Assisted living and the aging trajectory. *Journal of Women & Aging*, *20*(3-4), 309-327. https://doi.org/10.1080/08952840801985011

Winkler, E. A., Gardiner, P. A., Clark, B. K., Matthews, C. E., Owen, N., Healy, G. N., Winkler, E. A. H., Gardiner, P. A., Clark, B. K., Matthews, C. E., Owen, N., & Healy, G. N. (2012). Identifying sedentary time using automated estimates of accelerometer wear time. *British journal of sports medicine*, *46*(6), 436-442. https://doi.org/10.1136/bjsm.2010.079699

Wullems, J. A., Verschueren, S. M. P., Degens, H., Morse, C. I., & Onambélé, G. L. (2016). A review of the assessment and prevalence of sedentarism in older adults, its physiology/health impact and non-exercise mobility counter-measures. *Biogerontology*, *17*(3), 547-565. https://doi.org/10.1007/s10522-016-9640-1

Yen, H. Y., & Chiu, H. L. (2021). Virtual Reality Exergames for Improving Older Adults' Cognition and Depression: A Systematic Review and Meta-Analysis of Randomized Control Trials. *J Am Med Dir Assoc*, *22*(5), 995-1002. https://doi.org/10.1016/j.jamda.2021.03.009

Yerrakalva, D., Yerrakalva, D., Hajna, S., & Griffin, S. (2019). Effects of Mobile Health App Interventions on Sedentary Time, Physical Activity, and Fitness in Older Adults: Systematic Review and Meta-Analysis. *J Med Internet Res*, *21*(11), e14343.

Zhao, R. Q., Feng, F. F., & Wang, X. Z. (2017). Exercise interventions and prevention of fall-related fractures in older people: A meta-analysis of randomized controlled trials. *International journal of epidemiology*, *46*(1), 149-161. https://doi.org/10.1093/ije/dyw142

Zubala, A., MacGillivray, S., Frost, H., Kroll, T., Skelton, D. A., Gavine, A., Gray, N. M., Toma, M., & Morris, J. (2017). Promotion of physical activity interventions for community dwelling older adults: A systematic review of reviews. *PLoS ONE*, *12*(7), e0180902. https://doi.org/10.1371/journal.pone.0180902

CHAPTER II

(Paper 1)

Device-Measured Sedentary Behavior in Oldest Old Adults: A Systematic Review and Meta-Analysis[1]

Abstract

Sedentary behavior contributes to health decline and frailty in older adults, especially the oldest old. The purpose of this systematic review was to synthesize evidence describing the volume of device-measured sedentary behavior and factors that influence sedentary behavior in community-dwelling adults aged 80 and older. Four electronic databases were searched in August 2018; the search was updated in September 2019 and December 2020. Twenty-one articles representing 16 unique datasets from six countries met inclusion criteria. Various devices and data processing methods were used to measure sedentary behavior; the most common device was the ActiGraph accelerometer. Sedentary time during the waking day ranged from 7.6-13.4 hours/day. Studies using similar measurement methods (hip-worn ActiGraph with uniaxial cut-point <100 counts per minute) had a weighted mean of 10.6 hours/day. Subgroup analyses revealed that male gender and age ≥85 may contribute to increased sedentary behavior. Only seven individual articles examined factors that influence sedentary behavior in the 80 and older age group; older age, male gender, non-Hispanic white race/ethnicity, social disadvantage, and declining

[1] This paper was published in *Preventive Medicine Reports (2021)*

cognitive function (in men) were associated with increased sedentary behavior. In conclusion, the oldest old are highly sedentary and little is known about factors that influence their sedentary behavior.

Introduction

Older adults are the most sedentary age group in the United States (Matthews et al., 2008). Growing evidence suggests that sedentary behavior (SB) contributes to health decline and frailty in older adults, especially the oldest old (≥80-85 years) (Dogra & Stathokostas, 2012; Leitzmann et al., 2018; Valenzuela et al., 2019). SB is defined as any behavior with a low energy expenditure (≤ 1.5 metabolic equivalents) in a sitting, reclining, or lying position while awake (Tremblay et al., 2017). Increased SB has been associated with lower odds of successful aging in physical, psychological, and sociological domains (Dogra & Stathokostas, 2012); increased risk of developing physical frailty (Song et al., 2015); and increased risk of disability in activities of daily living and instrumental activities of daily living (Chen et al., 2016; Dunlop et al., 2015). Although the *Physical Activity Guidelines for Americans* now suggest that older adults replace sedentary time with light physical activity (*Physical activity guidelines for Americans, 2nd edition*, 2018), no guidelines currently exist on limiting SB to a specific number of hours per day.

While most SB literature has been based on self-reported sedentary time, evidence based on device-measured SB is increasing (Leitzmann et al., 2018). Because SB is typically not a planned activity and takes place in the context of everyday life, recalling daily volumes of sedentary time is difficult and self-report measures are often biased (Gennuso et al., 2015). Devices such as accelerometers and inclinometers are precise, can be used to measure SB objectively, and are more accurate than self-report (Kozey-Keadle et al., 2011).

Previous reviews found that older adults, aged ≥60 or 65, are sedentary; device-measured SB ranged from 8.5-9.6 hours/day (Harvey et al., 2015; Wullems et al., 2016). One review that synthesized literature on determinants of SB in adults 65 and older found evidence for personal (age, retirement, obesity, health status), interpersonal (loneliness/living alone), and environmental (mode of transportation, housing type, neighborhood characteristics) factors (Chastin et al., 2015). However, since functional fitness and physical capability generally decrease with age (Cooper et al., 2011; Milanović et al., 2013), SB patterns and influencing factors may be different for the younger old (60 or 65-80 years) compared to the oldest old (≥80-85 years).

While much evidence for SB in older adults does exist, fewer studies focus on those ≥80 years. Because these individuals are at higher risk for health decline and frailty and this population is growing as people live longer (Barnett et al., 2012; Lee et al., 2020; Zhang et al., 2020), a review focused on the volume of SB and the factors that influence SB in the oldest old population is needed. Synthesizing the existing evidence about the volume of SB in this age group will be helpful as more is known about what thresholds of sedentary time are associated with harmful health effects (Ku et al., 2018). Also, understanding factors that influence SB may guide the development of interventions to reduce SB; this could promote aging in place by retention of functional abilities, prevent or treat frailty, improve quality of life into later years, and reduce healthcare utilization and costs associated with low physical function and frailty (Cheng et al., 2020; Copeland et al., 2017; Hoogendijk et al., 2019; Kim & Lee, 2019; Lerma et al., 2018). This systematic review of the literature aims to characterize the volume of device-measured SB and to identify factors that may influence SB in community-dwelling adults aged 80 and older.

Methods

This review was conducted according to systematic review guidelines by Siddaway et el (Siddaway et al., 2019). and reported according to guidelines from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2009). In consultation with a health sciences informationist, a search was conducted in four databases: PubMed, CINAHL, AgeLine, and Scopus. Search terms were related to older adults, SB, and devices that measure SB. Subject headings and indexed terms were included as appropriate for each database (see full search strategies in Box 1). The search was initially conducted in August 2018 and updated using the same methods in September 2019 and December 2020. The search was not restricted by year of publication.

Articles included in this systematic review met all of the following criteria: used observational/population-based research design, included participants who were community dwelling and aged 80 years and older, reported device-measured sedentary time or percentage of the day spent sedentary, were conducted in a free-living environment, and were written in English. Studies were excluded if they provided less than three days of activity monitoring. To avoid biasing the results of this review, studies were excluded if their recruitment targeted subjects with a specific activity level or a specific condition or disease (e.g., osteoarthritis, obesity, or diabetes). Studies were not automatically excluded if they included subjects younger than 80 years; however they needed to report a sedentary time specific to subjects ≥80 years.

After removing duplicate articles, two independent reviewers screened each title/abstract using a checklist of the inclusion and exclusion criteria. The full texts of studies that appeared to meet criteria were then reviewed, and any discrepancies in the findings of the two reviewers were resolved in meetings. Additional searching for qualifying studies included checking the reference lists of included articles, using Scopus to find articles that cited the included studies, and locating any qualifying grey literature using Google searches for keywords *sedentary behavior* and *older adults* on the websites of relevant professional organizations (American College of Sports Medicine, Society of Behavioral Medicine, Sedentary Behavior Research Network). These additional articles were reviewed via the same process used for those retrieved from the databases. Articles meeting all inclusion and exclusion criteria were included in the systematic review. A PRISMA diagram outlining the literature review process is shown in Figure 2.1.

Two independent reviewers extracted the following data from each article: the country where the study was conducted, sample size, study design, devices used to measure SB, device wear location, minimum number of valid monitoring days, non-wear algorithm used (if applicable), uniaxial or triaxial data used (if applicable), cut-points used to determine SB or definition of SB used, when subjects were asked to wear the device (waking hours vs. 24 hours/day), how sleep time was addressed with 24-hour data, mean wear time, sedentary time reported (with measure of variability), and factors that influenced SB or were associated with SB. Some studies reported separate estimates of sedentary time by gender or narrower age categories, which we also extracted. Sedentary times reported as minutes/day were converted to hours/day and measures of variability were converted to standard errors and 95% confidence intervals. We attempted to contact authors of studies that were potentially eligible for the meta-analysis, but were missing the sample size for subjects ≥80. Two reviewers conducted a quality assessment of each article using the Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies and rated each article as *good*, *fair*, or *poor* based on 14 criteria such as participation rate; application of inclusion/exclusion criteria; sample size justification; timing, validity, and reliability of exposure and outcome measures; loss to follow-up; and adjustment for confounding variables (National Heart, Lung, and Blood, 2014).

For studies that used similar measurement methods, sedentary time results were quantitatively synthesized to report an overall mean sedentary time weighted by the inverse standard error with a fixed effects model. We also conducted subgroup analyses to compare mean sedentary times by gender and age (younger vs. older) subcategories. Forest plots were created with weighted mean sedentary times and the I^2 statistic was used to assess heterogeneity. These analyses were conducted with Stata 15.1 software (StataCorp, 2017). Measurement approaches (devices, cut-points, non-wear algorithms) and any factors associated with SB were summarized.

Results

Of the 2,600 non-duplicate articles retrieved from the four databases and additional searches, a total of 21 met all criteria for inclusion (see Table 2.1). Articles were published from 2011-2020 and represented 16 unique datasets from studies conducted in six countries (Iceland, Japan, Norway, Portugal, United Kingdom, United States). Three of the datasets were nationally representative samples from Norway (Sagelv et al., 2019), Portugal (Santos et al., 2018), and the United States (two waves of the National Health and Nutrition Examination Survey) (Chastin et al., 2014; Dunlop et al., 2015; Evenson et al., 2012; Evenson et al., 2014). Twelve articles utilized data from large cohort studies (Arnardottir et al., 2013; Berkemeyer et al., 2016; Chen et al., 2015; Çukić et al., 2018; Hooker et al., 2016; Jefferis et al., 2015; Okely et al., 2019; Rosenberg et al., 2020; Sagelv et al., 2019; Shaw, Cukic, et al., 2017; Shaw, Čukić, et al., 2017; Suzuki et al., 2020).

According to the quality assessment, three included studies were rated as *good* and the other 18 were *fair*. The most common risks of bias were related to the cross-sectional design of 16 studies because sedentary time was measured at the same time point as any potential influencing factors. Other risks of bias were related to participation rates <20% and lack of sample size justifications.

The majority of studies used various ActiGraph accelerometer models to measure SB (Arnardottir et al., 2013; Berkemeyer et al., 2016; Chastin et al., 2014; Davis et al., 2011; Dunlop et al., 2015; Evenson et al., 2012; Evenson et al., 2014; Jefferis et al., 2015; Lohne-Seiler et al., 2014; Rosenberg et al., 2020; Sagelv et al., 2019; Santos et al., 2018; Suzuki et al., 2020). Two studies used Active Style Pro (Chen et al., 2015; Yonemoto et al., 2019) and one study each used Actical (Hooker et al., 2016) and GENEActiv (Ryan et al., 2019) accelerometers. Five articles representing two datasets utilized the activPAL device (four articles reported results from the same sample of subjects) (Çukić et al., 2018; Okely et al., 2019; Rosenberg et al., 2020; Shaw, Cukic, et al., 2017; Shaw, Čukić, et al., 2017). Accelerometer devices were mainly worn at the hip/waist; in one study, the accelerometer was worn on the thigh (Ryan et al., 2019). ActivPAL devices were worn on the anterior thigh (Çukić et al., 2018; Okely et al., 2019; Rosenberg et al., 2020; Shaw, Cukic, et al., 2017; Shaw, Čukić, et al., 2017). Most ActiGraph studies used uniaxial (vertical) data and a cut-point of <100 counts per minute to define SB. Two ActiGraph studies used triaxial data with cut-points of ≤18 vector magnitude counts per 15 seconds (Rosenberg et al., 2020) and <150 vector magnitude counts per minute (Sagelv et al., 2019). Studies that used other accelerometers either used smaller cut-points (<50 counts per minute) (Hooker et al., 2016), or metabolic equivalents (≤1.5 METS) to define SB (Chen et al., 2015; Ryan et al., 2019; Yonemoto et al., 2019). In the articles that used activPAL, SB was determined by thigh position (sitting or lying). Most studies used a non-wear algorithm to define times when the device was likely removed; minimum lengths of time ranged from 20-150 minutes of little or no activity. Appendix Table A.1 provides a further description of data processing methods and wear time.

Reported sedentary times ranged from 7.6 to 13.4 hours during the waking day. One study reported means of 13.3 and 14.2 sedentary hours/day (for women and men respectively), but did not exclude sleep time (Suzuki et al., 2020). Some articles used a percentage of the waking day to report sedentary time, which ranged from 68.0% to 72.5% (Chastin et al., 2014; Çukić et al., 2018; Okely et al., 2019; Shaw, Cukic, et al., 2017; Shaw, Čukić, et al., 2017). We will primarily focus on studies that reported sedentary hours or minutes/day.

We calculated the weighted mean sedentary time for studies that used hip/waist-worn ActiGraph uniaxial data with a SB cut-point of <100 counts per minute, the most common measurement method. We were not able to calculate weighted means of sedentary time for studies using alternate measurement methods because other devices and other ActiGraph cut-points were used in only one or two studies each. To avoid including duplicate subjects, only one NHANES estimate was included in the weighted mean; we included the study that required four (vs. three) valid days of monitoring and had the larger sample size (Evenson et al., 2014). One uniaxial ActiGraph study could not be included in the weighted mean because it reported the median sedentary time due to non-normal distribution (Berkemeyer et al., 2016). Mean sedentary estimates from seven articles (eight datasets) representing 1,970 total subjects were used to calculate the weighted mean (Arnardottir et al., 2013; Davis et al., 2011; Evenson et al., 2014; Jefferis et al., 2015; Lohne-Seiler et al., 2014; Sagelv et al., 2019; Santos et al., 2018), which was 10.6 hours/day (95% CI 10.5, 10.7) during waking hours. Four studies included in the weighted mean reported results by gender (Arnardottir et al., 2013; Jefferis et al., 2015; Lohne-Seiler et al., 2014; Santos et al., 2018); the subgroup analysis found significantly higher sedentary behavior in men (10.6 hours/day; 95% CI 10.5, 10.7; n=655 total subjects) than in women (10.0 hours/day; 95% CI 9.9, 10.2; n=283 subjects). Four studies included in the weighted mean reported results by narrower age categories (Arnardottir et al., 2013; Davis et al., 2011; Lohne-Seiler et al., 2014; Santos et al., 2018); the subgroup analysis found significantly higher sedentary behavior in the ≥85 age group (10.5 hours/day; 95% CI 10.3, 10.7; n=195 total subjects) than in those 80-84 or 80-85 (10.2 hours/day; 95% CI 10.0, 10.3; n=360 subjects). Forest plots and I^2 values are displayed in Figures 2.2-2.4.

Studies that used activPAL, GENEActiv, and ActiGraph triaxial data reported sedentary estimates fairly similar to the uniaxial ActiGraph weighted mean (9.5-11.6 hours/day) (Rosenberg et al., 2020; Ryan et al., 2019; Sagelv et al., 2019). The two studies that used the Active Style Pro device reported lower sedentary estimates (7.6-8.9 hours/day)(Chen et al., 2015; Yonemoto et al., 2019) and the study that used Actical reported higher sedentary time (13.4 hours/day) (Hooker et al., 2016).

Only seven articles examined factors associated with SB in the ≥80 age group (Çukić et al., 2018; Davis et al., 2011; Evenson et al., 2012; Okely et al., 2019; Shaw, Cukic, et al., 2017; Shaw, Čukić, et al., 2017; Suzuki et al., 2020); few of these factors were shown to be significant. In one study, older age was associated with increased SB: participants age 85 and older were more sedentary than participants age 80-84 (Davis et al., 2011). In two studies, sedentary time differed by gender, with men being more sedentary than women (Evenson et al., 2012; Suzuki et al., 2020); however, another study did not find gender differences (Çukić et al., 2018). For race/ethnicity, non-Hispanic whites had higher SB than did Hispanics (Evenson et al., 2012).

Greater social disadvantage was associated with increased SB according to measures of residential area deprivation, social class, and car ownership (Shaw, Cukic, et al., 2017). One cross-sectional study found that declining cognitive function was associated with increased SB in men (Suzuki et al., 2020), but a longitudinal study found that cognitive ability did not predict SB (Çukić et al., 2018). Additional variables found to be non-significant in their association with SB in this age group included depression, anxiety, and neighborhood and social environment (Okely et al., 2019; Shaw, Čukić, et al., 2017). Although studies reported other factors associated with SB in older adults, they were not specific to those ≥80 years.

Discussion

This review revealed that adults aged 80 and older are sedentary for an average of 10.6 hours during the waking day, as measured by ActiGraph uniaxial methods. Few of the reviewed studies evaluated factors that might influence SB in this age group; however, five factors were shown to be associated with increased SB—older age, male gender, non-Hispanic white race/ethnicity, social disadvantage, and declining cognitive function in men.

The mean device-measured sedentary time in the oldest old (≥80) was approximately one to two hours/day greater than that found in two previous reviews of adults aged 60 and older, which reported 9.4 and 8.5-9.6 hours of device-measured SB during the waking day (Harvey et al., 2015; Wullems et al., 2016). This increase in SB with age is consistent with previous research of middle-aged and older adults where physical activity declined with age (Diaz et al., 2016; Schrack et al., 2014). Taken together, the evidence suggests that this is a robust and well documented relationship.

Our meta-analytic comparisons of mean sedentary time by gender revealed significantly higher sedentary behavior in men across four studies; however, these gender differences may be due to the high heterogeneity among studies (I^2=87.7% overall). Similarly, the comparisons of narrower age categories revealed higher sedentary behavior in subjects ≥85 years compared to those 80-84 or 80-85, but we again observed high heterogeneity among studies (I^2=87.9% overall). While these meta-analytic results were consistent with the results of the individual included studies, further research is needed to establish the effects of gender and age on SB within the oldest old population.

Cultural differences may influence SB in various countries (Koyanagi et al., 2018). The review did not include results from enough countries to draw conclusions, but it is interesting to note that the lowest estimates of sedentary time for men and women combined were from studies conducted in Japan (7.6 hours/day and 8.1 hours/day) (Chen et al., 2015; Yonemoto et al., 2019) and the highest was from a study conducted in the United States (13.4 hours/day) (Hooker et al., 2016). This is consistent with World Health Organization data showing that adults in the United States are less active than adults in Japan (WHO, 2018). However, differences in the devices used, data processing methods, and sample age (≥80 vs. ≥85 years) may have also contributed to the large difference in sedentary time between these studies. Because the triaxial Active style Pro device used in the Japanese studies may measure significantly less SB than the ActiGraph with the commonly used uniaxial cut-point of <100 counts per minute for SB (Yano et al., 2019), the lower estimates maybe have resulted from device differences.

Even though the majority of studies used ActiGraph devices, results from different ActiGraph models may not be comparable (Cain et al., 2013). Other variations in processing methods, such as non-wear algorithm length and choice of cut-points to define SB, will also affect sedentary time estimates (Gorman et al., 2014; Mailey et al., 2014). Included studies using uniaxial ActiGraph data all used a cut-point of <100 counts per minute for SB. While this cut-point is commonly used, evidence suggests that a lower cut-point is more appropriate when using the ActiGraph with older adults (Aguilar-Farias et al., 2014; Koster et al., 2016). The low-level light physical activities commonly seen in older adults may get counted as SB when using the cut-point of <100 counts per minute, thereby overestimating sedentary time (Koster et al., 2016). Because this cut-point was also used in previous studies with *younger* older adults, we can still conclude the oldest old age group is more sedentary than those age 60-80.

This review identified that age, gender, race/ethnicity, social disadvantage, and cognitive function may be associated with SB in adults aged 80 and older. However, except for gender, these factors were significant in only one study each, which will require additional studies to confirm them. In a previous review, additional factors were associated with SB in adults age 65 and older, including multiple personal factors (obesity, health status, retirement), environmental housing and neighborhood factors, and interpersonal factors related to living situations (Chastin et al., 2015). The small number of factors associated with SB in the current review indicates that the factors associated with SB have been inadequately studied among the oldest old.

Due to their cross-sectional design, the quality of the majority of included studies was rated as *fair*. The cross-sectional design presents a risk of bias for identifying factors that influence SB because it is difficult to assess the direction of causality. However, because articles with representative and larger samples were included, the cross-sectional design does not present a risk of bias for the first aim of this review, which is identifying the volume of SB in the targeted age group. Device measured SB reduced the risk of bias in all studies, though the differences in measurement methods between studies presented challenges for synthesizing results.

Limitations and significant gaps in the science included less than optimal SB measures, infrequent analysis of factors influencing SB, and the use of activPAL, the most valid measure of SB (Kozey-Keadle et al., 2011), in only two unique studies. Also, uniaxial accelerometer cut-points for SB may not have been appropriate. Additionally, we found no evidence of modifiable risk factors for SB, factors that could be targeted in an intervention to reduce SB in the oldest old. A limitation of this review is that we only included articles published in English. Exclusion of articles in other languages could mean we are missing populations with potentially different patterns of SB.

This review has several important implications. The weighted mean of 10.6 sedentary hours/waking day highlights the magnitude of the SB problem and could be utilized to educate the oldest old adults on the potential for decreasing sedentary time. Although the factors associated with SB in this review need further verification, they provide preliminary evidence that certain subgroups of the oldest old may be at higher risk for elevated SB. This review of SB in community-dwelling oldest old will allow for comparison with older adults residing in residential care such as assisted living, most of whom are in this oldest old age group (National Center for Health Statistics issuing & National Study of Long-Term Care, 2019).

In conclusion, this review found that adults age 80 and older are highly sedentary with a mean of 10.6 sedentary hours during the waking day. It is important to acknowledge that SB estimates were influenced by measurement methodology. Meta-analytic subgroup analyses revealed that older age and male gender may be related to increased sedentary time. Older age, male gender, non-Hispanic white race/ethnicity, social disadvantage, and cognitive function (in men) were the only factors found in individual studies to be associated with increased SB in this age group. These results highlights the need for future research to identify additional factors associated with SB.

Box 2.1. Search strategies by database.

<u>AgeLine</u>
(DE "80+" OR DE "85+" OR DE "90+" OR DE "95+" OR DE "Centenarians" OR DE "Old Old" OR DE "Older Adults" OR DE "Young Old" OR (elderly OR "senior citizen" OR geriatric OR "older adult")) AND (Accelerometry OR accelerometer OR accelerometers OR Actigraphy OR actigraph OR actigraphs OR activpal OR Actical OR sensecam OR inclinometer OR inclinometers OR inclinometric OR inclinometry) AND ((DE "Sedentary Lifestyle") OR (Sedentary OR inactivity OR inactive))

<u>CINAHL</u>
((MH "Geriatrics") OR (MH "Aged") OR (MH "Aged, 80 and Over") OR (elderly OR "senior citizen" OR geriatric OR "older adult")) AND ((MH "Accelerometers") OR (MH "Accelerometry") OR (MH "Actigraphy") OR (Accelerometry OR accelerometer OR accelerometers OR Actigraphy OR actigraph OR actigraphs OR activpal OR Actical OR sensecam OR inclinometer OR inclinometers OR inclinometric OR inclinometry)) AND ((MH "Life Style, Sedentary") OR (Sedentary OR inactivity OR inactive))

<u>PubMed</u>
("Sedentary Behavior"[Mesh] OR "Sitting Position"[Mesh] OR "Sedentary Lifestyle"[Mesh] OR Sedentary[tw] OR inactivity[tw] OR inactive[tw]) AND ("Accelerometry"[Mesh] OR Accelerometry[tw] OR accelerometer[tw] OR accelerometers[tw] OR "Actigraphy"[Mesh] OR Actigraphy[tw] OR actigraph[tw] OR actigraphs[tw] OR activpal[tw] OR Actical[tw] OR sensecam[tw] OR inclinometer[tw] OR inclinometers[tw] OR inclinometric[tw] OR inclinometry[tw]) AND ("Geriatrics"[Mesh] OR "Aged, 80 and over"[Mesh] OR "Aged"[Mesh] OR elderly[tw] OR "senior citizen"[tw] OR geriatric[tw] OR "older adult"[tw]))

<u>Scopus</u>
TITLE-ABS-KEY((elderly OR "senior citizen" OR geriatric OR "older adult") AND (Accelerometry OR accelerometer OR accelerometers OR Actigraphy OR actigraph OR actigraphs OR activpal OR Actical OR sensecam OR inclinometer OR inclinometers OR inclinometric OR inclinometry) AND (Sedentary OR inactivity OR inactive))

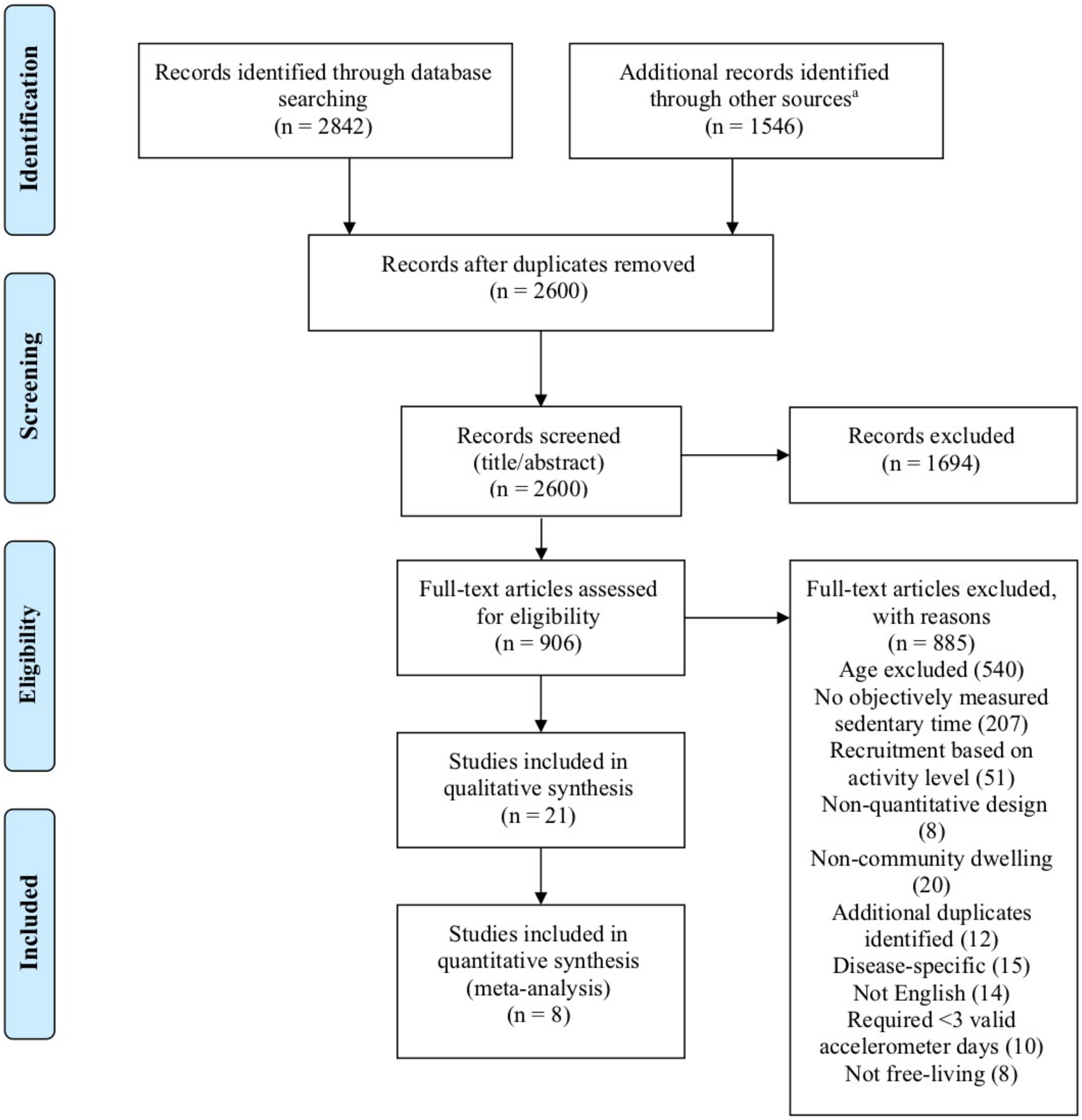

Figure 2.1. PRISMA flow diagram.

[a] Other sources included reference lists of included articles, articles that have cited included articles, and grey literature

Table 2.1 Data extracted from included studies for subjects 80 years and older

Article Author (Year Published)	Study Name, Country, Study design	Device Used, Cut-Point or Determination of SB, Uniaxial or Triaxial Data Used (if relevant)	Device Wear Location	Gender (if reported separately), Age Group (years)	Sample Size	Mean Sedentary Time per Day During Waking Hours[a]	95% Confidence Interval (or Interquartile Range)	Variables Analyzed for Association with Sedentary Behavior (only significant if noted)	Quality Assessment Rating
Arnardottir et al. (2013)[b]	AGESII-Reykjavik, Iceland, Cross-sectional	ActiGraph GT3X <100 cpm Uniaxial	Right hip	Women 80-84	90	10.0	9.7-10.3	-	Fair
				Women ≥85	65	10.2	9.9-10.5		
				Men 80-84	64	10.7	10.4-11.0		
				Men ≥85	28	10.7	10.1-11.3		
Berkemeyer et al. (2016)	EPIC-Norfolk, UK, Cross-sectional	ActiGraph GT1M <100 cpm Uniaxial	Right hip	Women >80	165[c]	10.2 (median)	9.4, 11.2 (IQR)	-	Fair
				Men >80	205[c]	10.7 (median)	9.7, 11.6 (IQR)		
Chastin et al. (2014)	NHANES 2005-2006, US, Cross-sectional	ActiGraph AM7164 <100 cpm Uniaxial	Hip	Women ≥80	-	71.1%	-	-	Fair
				Men ≥80	-	72.5%	-		
Chen et al. (2015)	Sasaguri Genkimon, Japan, Cross-sectional	Active Style Pro HJA-350IT ≤1.5 METs Triaxial	Waist	Women ≥80	198	7.8	7.5-8.1	-	Good
				Men ≥80	108	8.6	8.2-9.0		
Cukic et al. (2018)	Seniors USP Twenty-07 1930s cohort, Scotland, Longitudinal[d]	activPAL3c Thigh position	Dominant thigh	Women mean age 83[e]	65	68.5%	66.0-70.9%	Gender, cognitive ability	Good
				Men mean age 83[e]	54	68.0%	64.8-71.1%		

Article Author (Year Published)	Study Name, Country, Study design	Device Used, Cut-Point or Determination of SB, Uniaxial or Triaxial Data Used (if relevant)	Device Wear Location	Gender (if reported separately), Age Group (years)	Sample Size	Mean Sedentary Time per Day During Waking Hours[a]	95% Confidence Interval (or Interquartile Range)	Variables Analyzed for Association with Sedentary Behavior (only significant if noted)	Quality Assessment Rating
Davis et al. (2011)[b]	Project OPAL, UK, Cross-sectional	ActiGraph GT1M <100 cpm Uniaxial	Waist	80-84	59	11.0	10.6-11.4	Age[f]	Fair
				≥85	28	12.2	11.6-12.8		
Dunlop et al. (2015)	NHANES 2003-2004 and 2005-2006, US, Cross-sectional	ActiGraph AM7164 <100 cpm Uniaxial	Waist	≥80	494	9.6	9.4-9.8	-	Fair
Evenson et al. (2012)	NHANES 2003-2004 and 2005-2006, US, Cross-sectional	ActiGraph AM7164 <100 cpm Uniaxial	Right hip	Women ≥80	305	8.9	8.6-9.1	Gender[f], race/ethnicity[f]	Fair
				Men ≥80	278	9.4	9.1-9.6		
Evenson et al. (2014)[b]	NHANES 2003-2004 and 2005-2006, US, Cross-sectional	ActiGraph AM7164 <100 cpm Uniaxial	Right hip	≥80	555	10.2	10.0-10.4	-	Fair

Article Author (Year Published)	Study Name, Country, Study design	Device Used, Cut-Point or Determination of SB, Uniaxial or Triaxial Data Used (if relevant)	Device Wear Location	Gender (if reported separately), Age Group (years)	Sample Size	Mean Sedentary Time per Day During Waking Hours[a]	95% Confidence Interval (or Interquartile Range)	Variables Analyzed for Association with Sedentary Behavior (only significant if noted)	Quality Assessment Rating
(Evenson et al. 2014 continued)	Cardiovas-cular Health of Seniors and the Built Environment, US, Cross-sectional	ActiGraph GT1M and GT3X <100 cpm Uniaxial		≥80	155	10.6	10.2-11.0		
Hooker et al. (2016)	REGARDS, US, Cross-sectional	Actical <50 cpm	Right hip	≥85	-	13.4	13.2-13.5	-	Fair
Jefferis et al. (2015)[b]	British Regional Heart, UK, Cross-sectional	ActiGraph GT3X <100 cpm Uniaxial	Hip	Men ≥80	470	10.7	10.6-10.8	-	Fair
Lohn-Seiler et al. (2014)[b]	Unnamed, Norway, Cross-sectional	ActiGraph GT1M <100 cpm Uniaxial	Right hip	Women 80-85	37	9.9	9.5-10.3	-	Fair
				Men 80-85	28	9.8	9.4-10.2		
Okely et al. (2019)	Seniors USP Twenty-07 1930s cohort, Scotland, Longitudinal[d]	activPAL3c Thigh position	Domin-ant thigh	Mean age 83[e]	118	68.2%	66.2-70.1%	Depression, anxiety	Good

Article Author (Year Published)	Study Name, Country, Study design	Device Used, Cut-Point or Determination of SB, Uniaxial or Triaxial Data Used (if relevant)	Device Wear Location	Gender (if reported separately), Age Group (years)	Sample Size	Mean Sedentary Time per Day During Waking Hours[a]	95% Confidence Interval (or Interquartile Range)	Variables Analyzed for Association with Sedentary Behavior (only significant if noted)	Quality Assessment Rating
Rosenberg et al. (2020)[g]	Adult Changes in Thought, US, Cross-sectional	activPAL micro Thigh position	Thigh	80-84	173	10.1[h]	9.8-10.5	-	Fair
				85-89	114	10.4[h]	10.0-10.8		
				≥90	49	11.6[h]	11.1-12.1		
		ActiGraph wGT3X+ ≤18 vector magnitude counts/15 seconds Triaxial	Right supra-iliac crest	80-84	185	9.5	9.2-9.7		
				85-89	112	10.1	9.8-10.4		
				≥90	51	10.5	10.1-10.8		
Ryan et al. (2019)	Unnamed, UK, Cross-sectional	GENEActiv Original Seated/reclined position with <0.057 Residual G (<1.5 METs) Triaxial	Domin-ant thigh	≥84	9	10.5	9.7-11.2	-	Fair
Sagelv et al. (2019)[b]	Tromsø, Norway, Cross-sectional	ActiGraph wGT3X-BT <100 cpm Uniaxial	Right hip	≥80	235	11.6	11.4-11.8	-	Fair
		<150 vector magnitude cpm Triaxial				9.6	9.3-9.8		

Article Author (Year Published)	Study Name, Country, Study design	Device Used, Cut-Point or Determination of SB, Uniaxial or Triaxial Data Used (if relevant)	Device Wear Location	Gender (if reported separately), Age Group (years)	Sample Size	Mean Sedentary Time per Day During Waking Hours[a]	95% Confidence Interval (or Interquartile Range)	Variables Analyzed for Association with Sedentary Behavior (only significant if noted)	Quality Assessment Rating
Santos et al. (2018)[b]	Unnamed, Portugal, Cross-sectional	ActiGraph GT1M <100 cpm Uniaxial	Right hip	Women 80-84	44	9.5	8.8-10.2	-	Fair
				Women ≥85	47	10.2	9.7-10.7		
				Men 80-84	38	9.4	8.8-10.0		
				Men ≥85	27	9.6	8.8-10.4		
Shaw, Cukic, Deary, Gale, Chastin, Dall, Dontje et al. (2017)	Seniors USP Twenty-07 1930s cohort, Scotland, Longitudinal[d]	activPAL3c Thigh position	Domin-ant thigh	Mean age 83[e]	119	68.2%	66.2-70.2%	Neighborhood environment, social participation, social support, and home environment	Fair
Shaw, Cukic, Deary, Gale, Chastin, Dall, Skelton et al. (2017)	Seniors USP Twenty-07 1930s cohort, Scotland, Longitudinal[d]	activPAL3c Thigh position	Domin-ant thigh	Mean age 83[e]	119	68.2%	66.2-70.2%	Multiple measures of socioeconomic position[f]	Fair
Suzuki et al. (2020)[i]	Arakawa 85+, Japan, Cross-sectional	ActiGraph GT3X <100 cpm[j]	Waist	Women mean age 88	68	13.3[k]	12.7-13.9	Gender[f], cognitive function[l]	Fair
				Men mean age 88	68	14.2[k]	13.7-14.8		

Article Author (Year Published)	Study Name, Country, Study design	Device Used, Cut-Point or Determination of SB, Uniaxial or Triaxial Data Used (if relevant)	Device Wear Location	Gender (if reported separately), Age Group (years)	Sample Size	Mean Sedentary Time per Day During Waking Hours[a]	95% Confidence Interval (or Interquartile Range)	Variables Analyzed for Association with Sedentary Behavior (only significant if noted)	Quality Assessment Rating
Yonemoto et al. (2019)	Hisayama, Japan, Longitudinal	Active Style Pro HJA-350IT ≤1.5 METs Triaxial	Waist	≥80	23	7.6 (median, measured in 2009)	7.0-9.8 (IQR)	-	Fair
						8.9 (median, measured in 2012)	7.2-10.4 (IQR)		

Abbreviations: cpm, counts per minute; IQR, interquartile range; METs, metabolic equivalents; SB, sedentary behavior; UK, United Kingdom; US, United States. A hyphen indicates sample size was not reported for this age group, 95% CI was not reported and could not be calculated, or the study did not analyze any factors associated with sedentary behavior in subjects age ≥80.
[a] Hours/day or % of day in sedentary behavior (Mean unless otherwise noted as median)
[b] Unique studies included in meta-analysis
[c] Sample size was not reported in this article (and authors did not respond to a request for information), but was found in another article about the study sample (Wu et al., 2017)
[d] Predictors of sedentary behavior were measured in earlier waves of the study and sedentary behavior was measured in a later wave
[e] Note: the age range of this cohort was not totally clear, but subjects were born around 1932 (Benzeval et al., 2009) with a mean age of 83.4 (SD 0.62) strongly indicating they meet criteria for this review
[f] Factor was significantly associated with sedentary behavior
[g] This study excluded subjects in nursing homes, but it is not known if any subjects resided in other types of residential living
[h] Specifically sitting time (rather than sitting and lying)
[i] Authors labeled this study community-dwelling, but we noted that one female subject resided in a nursing home
[j] This study did not specify if uniaxial or triaxial data were analyzed
[k] This study did not exclude sleeping time
[l] Factor was significantly associated with sedentary behavior in men only

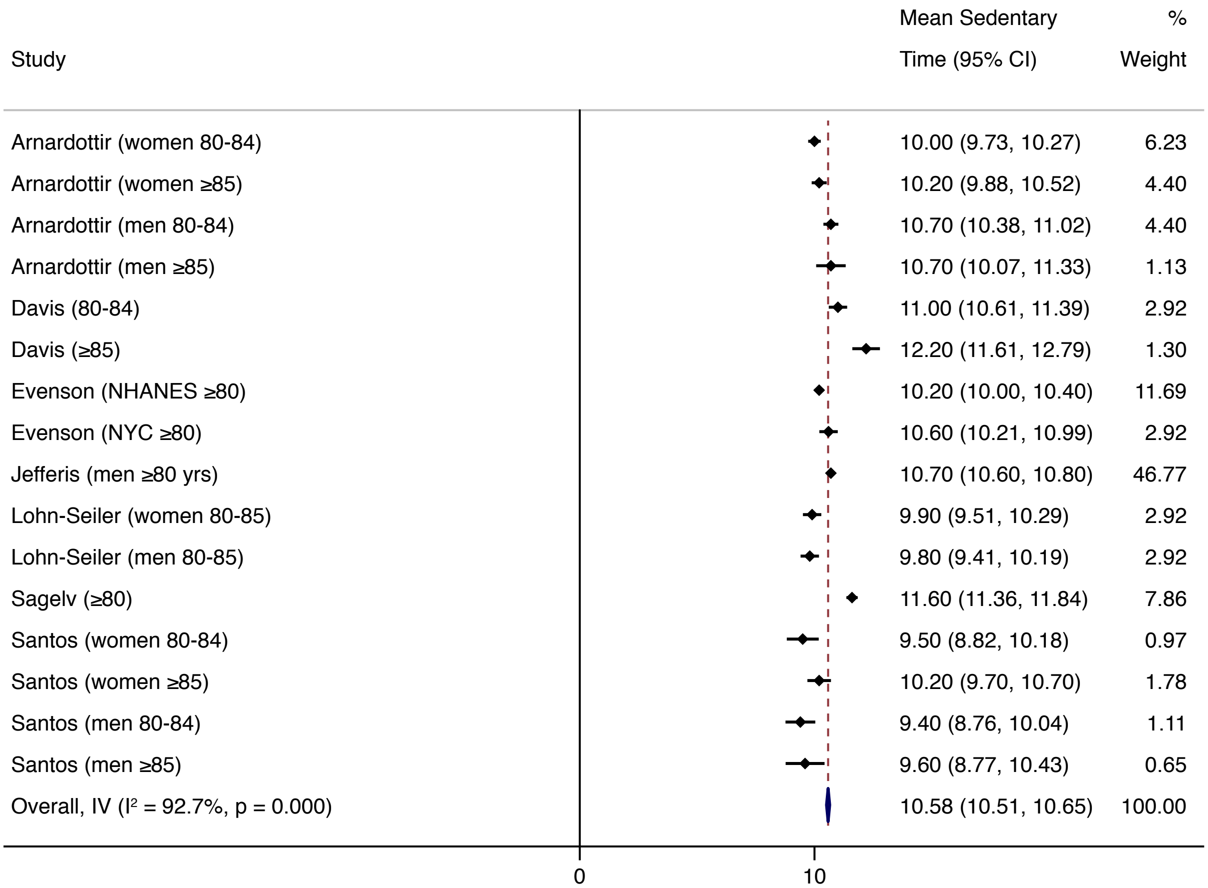

Figure 2.2. Forest plot of mean sedentary hours/waking day measured by hip-worn ActiGraph devices and processed using uniaxial data with a cut-point of <100 counts per minute.

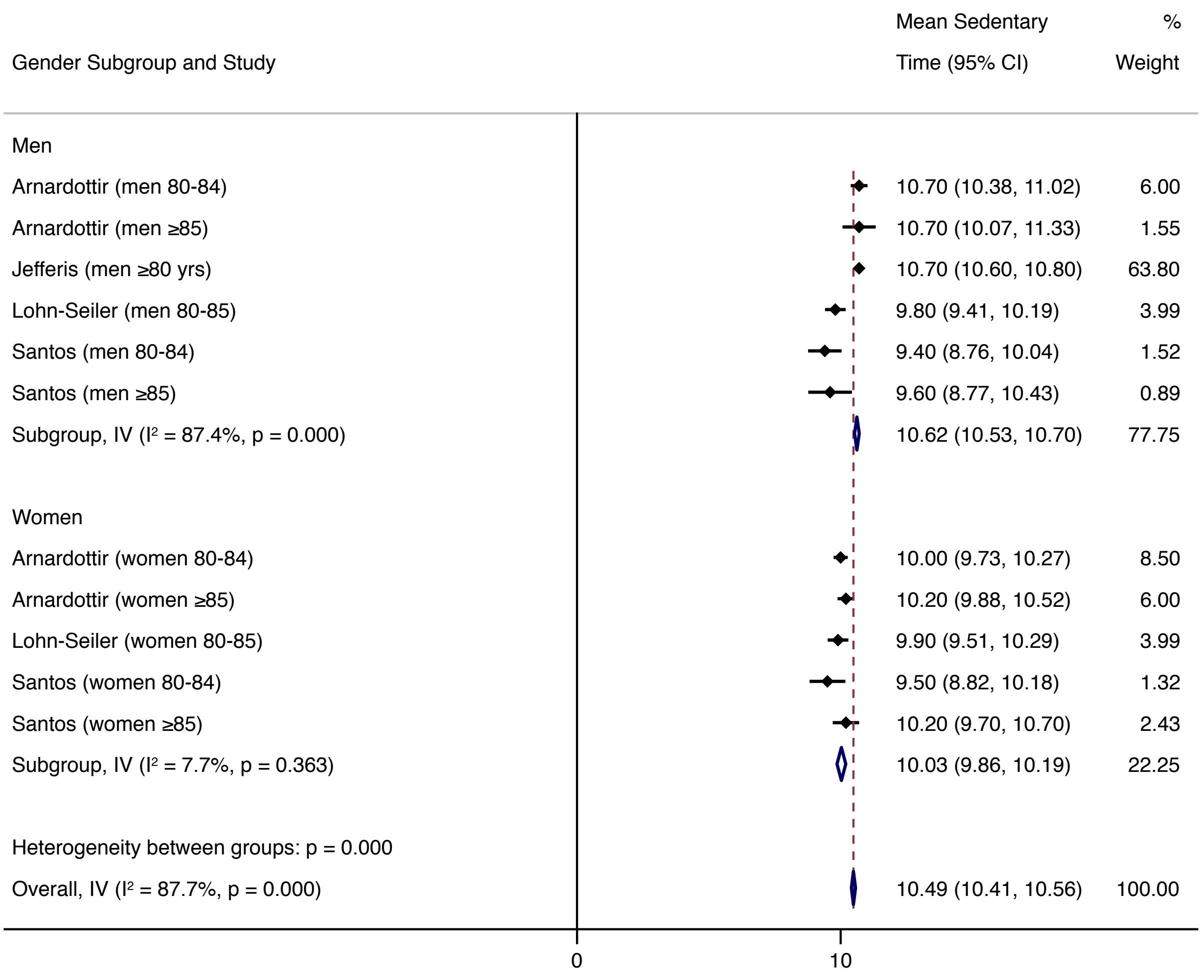

Figure 2.3. Forest plot of mean sedentary hours/waking day (measured by hip-worn ActiGraph devices and processed using uniaxial data with a cut-point of <100 counts per minute) by gender subgroups.

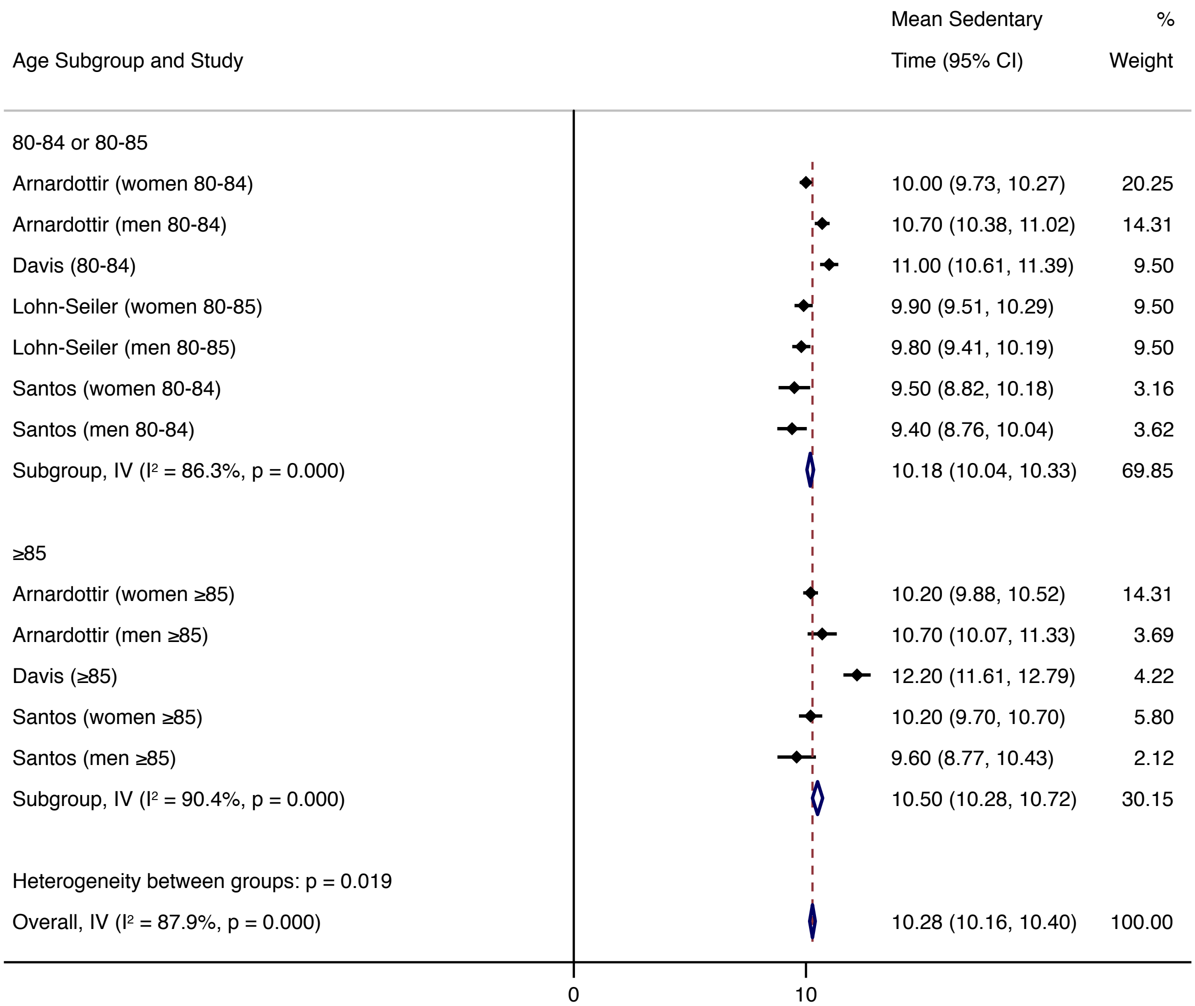

Figure 2.4. Forest plot of mean sedentary hours/waking day (measured by hip-worn ActiGraph devices and processed using uniaxial data with a cut-point of <100 counts per minute) by age subcategories.

References

Aguilar-Farias, N., Brown, W. J., & Peeters, G. M. (2014). ActiGraph GT3X+ cut-points for identifying sedentary behaviour in older adults in free-living environments. *Journal of science and medicine in sport*, *17*(3), 293-299. https://doi.org/10.1016/j.jsams.2013.07.002 [doi]

Arnardottir, N. Y., Koster, A., Domelen, D. R. V., Brychta, R. J., Caserotti, P., Eiriksdottir, G., Sverrisdottir, J. E., Launer, L. J., Gudnason, V., Johannsson, E., Harris, T. B., Chen, K. Y., & Sveinsson, T. (2013). Objective measurements of daily physical activity patterns and sedentary behaviour in older adults: Age, Gene/Environment Susceptibility-Reykjavik Study. *Age and Ageing*, *42*(2), 222-229. https://doi.org/10.1093/ageing/afs160

Barnett, K. P., Mercer, S. W. P., Norbury, M. M., Watt, G. P., Wyke, S. P., & Guthrie, B. P. (2012). Epidemiology of multimorbidity and implications for health care, research, and medical education: a cross-sectional study. *Lancet, The*, *380*(9836), 37-43. https://doi.org/10.1016/S0140-6736(12)60240-2

Benzeval, M., Der, G., Ellaway, A., Hunt, K., Sweeting, H., West, P., & Macintyre, S. (2009). Cohort Profile: West of Scotland Twenty-07 Study: Health in the Community. *International journal of epidemiology*, *38*(5), 1215-1223. https://doi.org/10.1093/ije/dyn213

Berkemeyer, K., Wijndaele, K., White, T., Cooper, A. J., Luben, R., Westgate, K., Griffin, S. J., Khaw, K. T., Wareham, N. J., & Brage, S. (2016). The descriptive epidemiology of accelerometer-measured physical activity in older adults. *The international journal of behavioral nutrition and physical activity*, *13*, 2-015-0316-z. https://doi.org/10.1186/s12966-015-0316-z [doi]

Cain, K. L., Conway, T. L., Adams, M. A., Husak, L. E., & Sallis, J. F. (2013). Comparison of older and newer generations of ActiGraph accelerometers with the normal filter and the low frequency extension. *The international journal of behavioral nutrition and physical activity*, *10*(1), 51-51. https://doi.org/10.1186/1479-5868-10-51

Chastin, S. F., Mandrichenko, O., Helbostadt, J. L., & Skelton, D. A. (2014). Associations between objectively-measured sedentary behaviour and physical activity with bone mineral density in adults and older adults, the NHANES study. *Bone*, *64*, 254-262. https://doi.org/10.1016/j.bone.2014.04.009 [doi]

Chastin, S. F. M., Buck, C., Freiberger, E., Murphy, M., Brug, J., Cardon, G., O'Donoghue, G., Pigeot, I., & Oppert, J. M. (2015). Systematic literature review of determinants of sedentary behaviour in older adults: A DEDIPAC study. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 127. https://doi.org/10.1186/s12966-015-0292-3

Chen, T., Narazaki, K., Haeuchi, Y., Chen, S., Honda, T., & Kumagai, S. (2016). Associations of Sedentary Time and Breaks in Sedentary Time With Disability in Instrumental Activities of Daily Living in Community-Dwelling Older Adults. *Journal of physical activity & health*, *13*(3), 303-309. https://doi.org/10.1123/jpah.2015-0090 [doi]

Chen, T., Narazaki, K., Honda, T., Chen, S., Haeuchi, Y., Nofuji, Y. Y., Matsuo, E., & Kumagai, S. (2015). Tri-axial accelerometer-determined daily physical activity and sedentary behavior of suburban community-dwelling older Japanese adults. *Journal of Sports Science and Medicine*, *14*(3), 507-514. https://www.scopus.com/inward/record.uri?eid=2-s2.0-84939168260&partnerID=40&md5=eb55cdc41467c5fd8c1e470de88ce938

Cheng, Y., Goodin, A. J., Pahor, M., Manini, T., & Brown, J. D. (2020). Healthcare Utilization and Physical Functioning in Older Adults in the United States. *Journal of the American Geriatrics Society*, *68*(2), 266-271. https://doi.org/10.1111/jgs.16260

Cooper, R., Hardy, R., Aihie Sayer, A., Ben-Shlomo, Y., Birnie, K., Cooper, C., Craig, L., Deary, I. J., Demakakos, P., Gallacher, J., McNeill, G., Martin, R. M., Starr, J. M., Steptoe, A., & Kuh, D. (2011). Age and gender differences in physical capability levels from mid-life onwards: the harmonisation and meta-analysis of data from eight UK cohort studies. *PLoS ONE*, *6*(11), e27899-e27899. https://doi.org/10.1371/journal.pone.0027899

Copeland, J. L., Ashe, M. C., Biddle, S. J. H., Brown, W. J., Buman, M. P., Chastin, S., Gardiner, P. A., Inoue, S., Jefferis, B. J., Oka, K., Owen, N., Sardinha, L. B., Skelton, D. A., Sugiyama, T., & Dogra, S. (2017). Sedentary time in older adults: a critical review of measurement, associations with health, and interventions. *British journal of sports medicine*, *51*(21), 1539-1539. https://doi.org/10.1136/bjsports-2016-097210

Çukić, I., Shaw, R., Der, G., Chastin, S. F. M., Dontje, M. L., Gill, J. M. R., Starr, J. M., Skelton, D. A., Radaković, R., Cox, S. R., Dall, P. M., Gale, C. R., & Deary, I. J. (2018). Cognitive ability does not predict objectively measured sedentary behavior: Evidence from three older cohorts. *Psychology and Aging*, *33*(2), 288-296. https://doi.org/10.1037/pag0000221

Davis, M. G., Fox, K. R., Hillsdon, M., Sharp, D. J., Coulson, J. C., & Thompson, J. L. (2011). Objectively measured physical activity in a diverse sample of older urban UK adults. *Medicine and science in sports and exercise*, *43*(4), 647-654. https://doi.org/10.1249/MSS.0b013e3181f36196 [doi]

Diaz, K. M., Howard, V. J., Hutto, B., Colabianchi, N., Vena, J. E., Blair, S. N., & Hooker, S. P. (2016). Patterns of Sedentary Behavior in US Middle-Age and Older Adults: The REGARDS Study. *Medicine and science in sports and exercise*, *48*(3), 430-438. https://doi.org/10.1249/MSS.0000000000000792 [doi]

Dogra, S., & Stathokostas, L. (2012). Sedentary behavior and physical activity are independent predictors of successful aging in middle-aged and older adults. *Journal of Aging Research*, *2012*, 190654. https://doi.org/10.1155/2012/190654 [doi]

Dunlop, D. D., Song, J., Arnston, E. K., Semanik, P. A., Lee, J., Chang, R. W., & Hootman, J. M. (2015). Sedentary time in US older adults associated with disability in activities of daily living independent of physical activity. *Journal of physical activity & health*, *12*(1), 93-101. https://doi.org/10.1123/jpah.2013-0311 [doi]

Evenson, Buchner, D. M., & Morland, K. B. (2012). Objective measurement of physical activity and sedentary behavior among US adults aged 60 years or older. *Preventing chronic disease*, *9*, E26. https://doi.org/E26 [pii]

Evenson, K. R., Morland, K. B., Fang, W., & Scanlin, K. (2014). Physical Activity and Sedentary Behavior Among Adults 60 Years and Older: New York City Residents Compared With a National Sample. *Journal of Aging & Physical Activity*, *22*(4), 499-507. https://doi.org/10.1123/JAPA.2012-0345

Gennuso, K. P., Matthews, C. E., & Colbert, L. H. (2015). Reliability and validity of two self-report measures to assess sedentary behavior in older adults. *Journal of physical activity & health*, *12*(5), 727-732. https://doi.org/10.1123/jpah.2013-0546 [doi]

Gorman, E., Hanson, H. M., Yang, P. H., Khan, K. M., Liu-Ambrose, T., & Ashe, M. C. (2014). Accelerometry analysis of physical activity and sedentary behavior in older adults: A systematic review and data analysis. *European Review of Aging and Physical Activity*, *11*(1), 35-49. https://doi.org/10.1007/s11556-013-0132-x

Harvey, J. A., Chastin, S. F., & Skelton, D. A. (2015). How sedentary are older people? A systematic review of the amount of sedentary behavior. *Journal of Aging and Physical Activity*, *23*(3), 471-487. https://doi.org/10.1123/japa.2014-0164 [doi]

Hoogendijk, E. O., Afilalo, J., Ensrud, K. E., Kowal, P., Onder, G., & Fried, L. P. (2019). Frailty: implications for clinical practice and public health. *The Lancet*, *394*(10206), 1365-1375. https://doi.org/10.1016/S0140-6736(19)31786-6

Hooker, S. P., Hutto, B., Zhu, W., Blair, S. N., Colabianchi, N., Vena, J. E., Rhodes, D., & Howard, V. J. (2016). Accelerometer measured sedentary behavior and physical activity in white and black adults: The REGARDS study. *Journal of science and medicine in sport*, *19*(4), 336-341. https://doi.org/10.1016/j.jsams.2015.04.006 [doi]

Jefferis, B. J., Sartini, C., Shiroma, E., Whincup, P. H., Wannamethee, S. G., & Lee, I. M. (2015). Duration and breaks in sedentary behaviour: accelerometer data from 1566 community-dwelling older men (British Regional Heart Study). *British journal of sports medicine*, *49*(24), 1591-1594. https://doi.org/10.1136/bjsports-2014-093514 [doi]

Kim, Y., & Lee, E. (2019). The association between elderly people's sedentary behaviors and their health-related quality of life: focusing on comparing the young-old and the old-old. *Health and quality of life outcomes*, *17*(1), 131. https://doi.org/10.1186/s12955-019-1191-0

Koster, A., Shiroma, E. J., Caserotti, P., Matthews, C. E., Chen, K. Y., Glynn, N. W., & Harris, T. B. (2016). Comparison of sedentary estimates between ActivPAL and hip- and wrist-worn ActiGraph. *Medicine and science in sports and exercise*, *48*(8), 1514-1522. https://doi.org/10.1249/MSS.0000000000000924 [doi]

Koyanagi, A., Stubbs, B., & Vancampfort, D. (2018). Correlates of sedentary behavior in the general population: A cross-sectional study using nationally representative data from six low- and middle-income countries. *PLoS ONE*, *13*(8), e0202222. https://doi.org/10.1371/journal.pone.0202222

Kozey-Keadle, S., Libertine, A., Lyden, K., Staudenmayer, J., & Freedson, P. S. (2011). Validation of wearable monitors for assessing sedentary behavior. *Medicine and science in sports and exercise*, *43*(8), 1561-1567. https://doi.org/10.1249/MSS.0b013e31820ce174 [doi]

Ku, P.-W., Steptoe, A., Liao, Y., Hsueh, M.-C., & Chen, L.-J. (2018). A cut-off of daily sedentary time and all-cause mortality in adults: a meta-regression analysis involving more than 1 million participants. *BMC medicine*, *16*(1), 74-74. https://doi.org/10.1186/s12916-018-1062-2

Lee, J., Lau, S., Meijer, E., & Hu, P. (2020). Living Longer, With or Without Disability? A Global and Longitudinal Perspective. *J Gerontol A Biol Sci Med Sci*, *75*(1), 162-167. https://doi.org/10.1093/gerona/glz007

Leitzmann, M., Jochem, C., & Schmid, D. (2018). *Sedentary Behavior Epidemiology*. Springer International Publishing.

Lerma, N. L., Cho, C. C., Swartz, A. M., Miller, N. E., Keenan, K. G., & Strath, S. J. (2018). Isotemporal Substitution of Sedentary Behavior and Physical Activity on Function. *Medicine and science in sports and exercise*, *50*(4), 792-800. https://doi.org/10.1249/MSS.0000000000001491

Lohne-Seiler, H., Hansen, B. H., Kolle, E., & Anderssen, S. A. (2014). Accelerometer-determined physical activity and self-reported health in a population of older adults (65-85 years): a cross-sectional study. *BMC Public Health*, *14*, 284-2458-2414-2284. https://doi.org/10.1186/1471-2458-14-284 [doi]

Mailey, E. L., Gothe, N. P., Wojcicki, T. R., Szabo, A. N., Olson, E. A., Mullen, S. P., Fanning, J. T., Motl, R. W., & McAuley, E. (2014). Influence of allowable interruption period on estimates of accelerometer wear time and sedentary time in older adults. *Journal of Aging and Physical Activity*, *22*(2), 255-260. https://doi.org/10.1123/japa.2013-0021 [doi]

Matthews, C. E., Chen, K. Y., Freedson, P. S., Buchowski, M. S., Beech, B. M., Pate, R. R., & Troiano, R. P. (2008). Amount of time spent in sedentary behaviors in the United States, 2003-2004. *American Journal of Epidemiology*, *167*(7), 875-881. https://doi.org/10.1093/aje/kwm390 [doi]

Milanović, Z., Pantelić, S., Trajković, N., Sporiš, G., Kostić, R., & James, N. (2013). Age-related decrease in physical activity and functional fitness among elderly men and women. *Clinical Interventions in Aging*, *8*, 549-556. https://doi.org/10.2147/CIA.S44112

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*, *339*(jul21 1), b2535-b2535. https://doi.org/10.1136/bmj.b2535

National Center for Health Statistics issuing, b., & National Study of Long-Term Care, P. (2019). *Long-term care providers and services users in the United States, 2015-2016 : data from the National Study of Long-Term Care Providers*. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics. https://purl.fdlp.gov/GPO/gpo128460

National Heart, Lung, and Blood Institute. (2014). *Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies* Bethesda: National Institutes of Health, Department of Health and Human Services https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools

Okely, J. A., Čukić, I., Shaw, R. J., Chastin, S. F., Dall, P. M., Deary, I. J., Der, G., Dontje, M. L., Skelton, D. A., & Gale, C. R. (2019). Positive and negative well-being and objectively measured sedentary behaviour in older adults: Evidence from three cohorts. *BMC geriatrics*, *19*(1). https://doi.org/10.1186/s12877-019-1026-1

Physical activity guidelines for Americans, 2nd edition. (2018).

Rosenberg, D., Walker, R., Greenwood-Hickman, M. A., Bellettiere, J., Xiang, Y., Richmire, K., Higgins, M., Wing, D., Larson, E. B., Crane, P. K., & LaCroix, A. Z. (2020). Device-assessed physical activity and sedentary behavior in a community-based cohort of older adults. *BMC Public Health*, *20*(1), 1256. https://doi.org/10.1186/s12889-020-09330-z

Ryan, D. J., Wullems, J. A., Stebbings, G. K., Morse, C. I., Stewart, C. E., & Onambele-Pearson, G. L. (2019). The difference in sleep, sedentary behaviour, and physical activity between older adults with 'healthy' and 'unhealthy' cardiometabolic profiles: a cross-sectional compositional data analysis approach. *Eur Rev Aging Phys Act*, *16*, 25. https://doi.org/10.1186/s11556-019-0231-4

Sagelv, E. H., Ekelund, U., Pedersen, S., Brage, S., Hansen, B. H., Johansson, J., Grimsgaard, S., Nordström, A., Horsch, A., Hopstock, L. A., & Morseth, B. (2019). Physical activity levels in adults and elderly from triaxial and uniaxial accelerometry. The Tromsø Study. *PLoS ONE*, *14*(12), e0225670. https://doi.org/10.1371/journal.pone.0225670

Santos, D. A., Judice, P. B., Magalhaes, J. P., Correia, I. R., Silva, A. M., Baptista, F., & Sardinha, L. B. (2018). Patterns of accelerometer-derived sedentary time across the lifespan. *J Sports Sci*, *36*(24), 2809-2817. https://doi.org/10.1080/02640414.2018.1474537

Schrack, J. A., Zipunnikov, V., Goldsmith, J., Bai, J., Simonsick, E. M., Crainiceanu, C., & Ferrucci, L. (2014). Assessing the "physical cliff": detailed quantification of age-related differences in daily patterns of physical activity. *The journals of gerontology.Series A, Biological sciences and medical sciences*, *69*(8), 973-979. https://doi.org/10.1093/gerona/glt199 [doi]

Shaw, R. J., Cukic, I., Deary, I. J., Gale, C. R., Chastin, S. F., Dall, P. M., Skelton, D. A., & Der, G. (2017). Relationships between socioeconomic position and objectively measured sedentary behaviour in older adults in three prospective cohorts. *BMJ Open*, *7*(6), e016436. https://doi.org/10.1136/bmjopen-2017-016436

Shaw, R. J., Čukić, I., Deary, I. J., Gale, C. R., Chastin, S. F. M., Dall, P. M., Dontje, M. L., Skelton, D. A., Macdonald, L., & Der, G. (2017). The influence of neighbourhoods and the social environment on sedentary behaviour in older adults in three prospective cohorts. *International Journal of Environmental Research and Public Health*, *14*(6). https://doi.org/10.3390/ijerph14060557

Siddaway, A. P., Wood, A. M., & Hedges, L. V. (2019). How to Do a Systematic Review: A Best Practice Guide for Conducting and Reporting Narrative Reviews, Meta-Analyses, and Meta-Syntheses. *Annual review of psychology*, *70*(1), 747-770. https://doi.org/10.1146/annurev-psych-010418-102803

Song, J., Lindquist, L. A., Chang, R. W., Semanik, P. A., Ehrlich-Jones, L., Lee, J., Min-Woong, S., & Dunlop, D. D. (2015). Sedentary Behavior as a Risk Factor for Physical Frailty Independent of Moderate Activity: Results From the Osteoarthritis Initiative. *American Journal of Public Health*, *105*(7), 1439-1445. https://doi.org/10.2105/AJPH.2014.302540

StataCorp. (2017). *Stata Statistical Software: Release 15*. In StataCorp LLC.

Suzuki, K., Niimura, H., Kida, H., Eguchi, Y., Kitashima, C., Takayama, M., & Mimura, M. (2020). Increasing light physical activity helps to maintain cognitive function among the community-dwelling oldest old population: a cross-sectional study using actigraph from the Arakawa 85+ study. *Geriatr Gerontol Int*, *20*(8), 773-778. https://doi.org/10.1111/ggi.13967

Tremblay, M. S., Aubert, S., Barnes, J. D., Saunders, T. J., Carson, V., Latimer-Cheung, A. E., Chastin, S. F. M., Altenburg, T. M., & Chinapaw, M. J. M. (2017). Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome.

International Journal of Behavioral Nutrition and Physical Activity, *14*(1), 1-17. https://doi.org/10.1186/s12966-017-0525-8

Valenzuela, P. L., Castillo-Garcia, A., Morales, J. S., Izquierdo, M., Serra-Rexach, J. A., Santos-Lozano, A., & Lucia, A. (2019). Physical Exercise in the Oldest Old. *Comprehensive Physiology*, *9*(4).

WHO. (2018). *Insufficient physical activity: Prevalence of Insufficient physical activity among adults, age 18+ (age standardized estimates), 2016: Both sexes* W. H. Organization.

Wu, Y. T., Luben, R., Wareham, N., Griffin, S., & Jones, A. P. (2017). Weather, day length and physical activity in older adults: Cross-sectional results from the European Prospective Investigation into Cancer and Nutrition (EPIC) Norfolk Cohort. *PLoS ONE*, *12*(5), e0177767. https://doi.org/10.1371/journal.pone.0177767 [doi]

Wullems, J. A., Verschueren, S. M. P., Degens, H., Morse, C. I., & Onambélé, G. L. (2016). A review of the assessment and prevalence of sedentarism in older adults, its physiology/health impact and non-exercise mobility counter-measures. *Biogerontology*, *17*(3), 547-565. https://doi.org/10.1007/s10522-016-9640-1

Yano, S., Koohsari, M. J., Shibata, A., Ishii, K., Mavoa, S., & Oka, K. (2019). Assessing Physical Activity and Sedentary Behavior under Free-Living Conditions: Comparison of Active Style Pro HJA-350IT and ActiGraphTM GT3X. *International Journal of Environmental Research and Public Health*, *16*(17), 3065. https://doi.org/10.3390/ijerph16173065

Yonemoto, K., Honda, T., Kishimoto, H., Yoshida, D., Hata, J., Mukai, N., Shibata, M., Hirakawa, Y., Ninomiya, T., & Kumagai, S. (2019). Longitudinal Changes of Physical Activity and Sedentary Time in the Middle-Aged and Older Japanese Population: The Hisayama Study. *J Phys Act Health*, *16*(2), 165-171. https://doi.org/10.1123/jpah.2017-0701

Zhang, Y., Xu, X.-J., Lian, T.-Y., Huang, L.-F., Zeng, J.-M., Liang, D.-M., Yin, M.-J., Huang, J.-X., Xiu, L.-C., Yu, Z.-W., Li, Y.-L., Mao, C., & Ni, J.-D. (2020). Development of frailty subtypes and their associated risk factors among the community-dwelling elderly population. *Aging*, *12*(2), 1128-1140. https://doi.org/10.18632/aging.102671

CHAPTER III

(Paper 2)

Comparative Assessment of ActiGraph Data Processing Techniques for Measuring Sedentary Behavior in Adults with COPD[2]

Abstract

Objective

The ActiGraph is commonly used for measuring sedentary behavior, but the best data processing technique is not established for sedentary adults with chronic illness. The purpose of this study was to process ActiGraph vertical axis and vector magnitude data with multiple combinations of filters, non-wear algorithm lengths, and cut-points and to compare ActiGraph estimates to activPAL-measured sedentary time in sedentary adults with chronic obstructive pulmonary disease.

Approach

This study was a secondary analysis of adults ≥50 years (N=59; Mean age: 69.4 years; N= 31 males) with chronic obstructive pulmonary disease. Participants wore *ActiGraph GT9X* and *activPAL3* for 7 days. ActiGraph vertical axis and vector magnitude data were processed using combinations of filters (normal, low frequency extension), non-wear algorithm lengths (60

[2] This paper was published in *Physiological Measurement (2021)*

90, 120 minutes), and cut-points for sedentary behavior previously validated in older adults (two for vertical axis and three for vector magnitude data). The Bland-Altman method was used to assess concordance between sedentary time measured with 30 ActiGraph techniques and activPAL-measured sedentary time.

Main Results

Agreement between the two devices was moderate to strong for all techniques; concordance correlations ranged from 0.614-0.838. Limits of agreement were wide. The best overall technique was vector magnitude data with low frequency extension filter, 120-minute non-wear algorithm, and <40 counts/15 seconds sedentary behavior cut-point (concordance correlation 0.838; mean difference -11.7 minutes/day).

Significance

This analysis supports the use of ActiGraph vector magnitude data and low frequency extension filter, but also demonstrates that other techniques may be acceptable with appropriate cut-points. These results can guide ActiGraph data processing decisions.

Introduction

Higher levels of sedentary behavior (SB) are a major health risk, especially for older adults with chronic illnesses such as chronic obstructive pulmonary disease (COPD) (Larson et al., 2014), but there are challenges with measuring SB. SB is any waking behavior characterized by low energy expenditure while sitting or lying (Kozey-Keadle et al., 2011). Researchers have primarily used two devices to measure SB objectively. The activPAL detects body position and is considered to be the most valid measure of SB (Kozey-Keadle et al., 2011). The activPAL measures SB as time spent in a sitting or lying position. The ActiGraph accelerometer was designed to measure physical activity (PA) rather than SB. It classifies SB as time spent below a certain threshold of activity and may misclassify standing as SB (Kozey-Keadle et al., 2011). Many researchers use the ActiGraph because they are interested in measuring the intensity of PA, which activPAL software does not provide. ActiGraph data processing involves several methodological decisions and although standards for processing PA data have been established, SB measurement requires unique strategies. No standard methodology for processing ActiGraph SB data exists, making it difficult to compare results across studies.

Options for data processing criteria include the use of vertical axis or vector magnitude data, normal or low frequency extension filter, duration of inactivity used to classify non-wear time, and the choice of cut-points to define SB. The optimal data processing technique for measuring sedentary behavior with an ActiGraph device is unknown and population specific.

Early ActiGraph models measured activity in the vertical axis only (Kelly et al., 2013). Current ActiGraph models are triaxial and measure activity in vertical, anteroposterior, and mediolateral axes (Kelly et al., 2013). Data from the three axes can be combined into vector magnitude units (Sasaki et al., 2011). Using vector magnitude may improve the precision of sedentary behavior measurement (Evenson et al., 2015). Many studies continue to analyze only vertical axis data, but use of vector magnitude is increasing.

Data from newer ActiGraph models are processed with either the default normal filter or the low frequency extension (LFE) filter. The LFE filter detects lower acceleration movements and is recommended for use in populations whose movements are often slower, such as older adults (Wanner et al., 2013). The LFE filter consistently results in lower estimates of sedentary time than the normal filter (Wallén et al., 2014; Wanner et al., 2013), but it is not known which filter results in the most valid SB measurement.

The most commonly used cut-point to define SB is <100 vertical axis counts per minute (Migueles et al., 2017). However, the optimal vertical axis cut-point in older adults may be much smaller (Aguilar-Farias et al., 2014; Koster et al., 2016). More recent SB cut-points have been developed for vector magnitude data (Evenson et al., 2015). Optimal cut-points may be population specific due to different behavior patterns.

The ActiGraph device may be removed for various reasons during the day, including bathing. Appropriately distinguishing between non-wear time and sedentary time is important because both will appear as periods of little or no activity. The chosen length of inactivity required to classify a period as non-wear time may affect sedentary time estimates (Mailey et al., 2014). The Choi algorithm was developed to refine the classification of non-wear time and defines non-wear time as at least 90 consecutive minutes of zero activity counts, but allows for up to 2 minutes of non-zero activity counts with 30 minutes of zero activity counts before and after the non-zero counts (Choi et al., 2011). Some studies in adult and older adult populations support non-wear algorithms with minimum windows of 120 minutes of consecutive zeros (Hutto et al., 2013; King et al., 2011). The Choi algorithm was developed with vertical axis data, but has also been used with vector magnitude data (Keadle et al., 2014).

While many studies have explored the effects of ActiGraph data processing techniques on the measurement of SB in the free living environment, most examined the effects of only a few different techniques and none provided a comprehensive comparison of multiple validated techniques against measurements acquired from the activPAL device. The purpose of this study was to compare ActiGraph and activPAL estimates of sedentary time in adults with COPD, processing the ActiGraph data with multiple different validated techniques and examining four processing criteria (type of data, filters, non-wear algorithm lengths, and SB cut-points). We aimed to identify the ActiGraph processing technique that resulted in sedentary time most closely matching the activPAL.

Methods

This study was a secondary analysis of data from an ongoing randomized controlled trial to promote PA in adults with COPD. The parent study was approved by University of Michigan IRBMED (HUM00119545) and informed consent was obtained; this secondary analysis was approved by University of Michigan IRB-HSBS (HUM00176645). Potential participants were recruited from a health system database using the Electronic Medical Record Search Engine (Hanauer et al., 2015). The sample included adults ≥50 years old with stable moderate to severe COPD who were inactive (< 30 minutes of moderate PA five days a week). Participants were excluded if they participated in pulmonary rehabilitation in the previous year or had major health problems limiting PA. Participants wore the *ActiGraph GT9X Link* accelerometer and the *activPAL3* monitor concurrently for 7 consecutive days. They were asked to keep a daily journal of the times they woke up and went to bed. Participants with no journal data were excluded from analysis. Data included in this analysis were collected at enrollment into the study, prior to initializing the intervention.

ActiGraph. The ActiGraph *GT9X Link* triaxial accelerometer is a small square device (14 grams; 3.5 x 3.5 x 1 cm) (ActiGraph, 2019) that measures intensity and duration of movements and allows researchers to classify time spent in various intensities of activity. The ActiGraph also has an inclinometer function, but this function has not been established as valid and will not be used in this analysis (Judice et al., 2019). Evidence suggests the ActiGraph is reliable for measuring SB in older adults (Hart et al., 2011), but validity of the ActiGraph for measuring sedentary time compared to direct observation has been low (Kozey-Keadle et al., 2011), in part because it is highly influenced by the choice of processing techniques (Aguilar-Farias et al., 2014).

ActivPAL. The *activPAL3* is a small rectangular device (15 grams; 5.3 x 3.5 x 0.7cm) that measures SB based on thigh position and acceleration (Kozey-Keadle et al., 2011). Evidence suggests the activPAL is reliable for measuring SB in older adults (Reid et al., 2013) and validity of activPAL for measuring SB compared to direct observation is strong in older adults with impaired function (Taraldsen et al., 2011).

Procedures and data processing. Participants were instructed to wear the ActiGraph at the right hip during waking hours, but to remove the device for showering or other water activities. Participants needed four or more valid days (device worn for at least 10 hours) to be included in analysis. ActiGraph devices were programmed with a sampling frequency of 30 Hz. ActiGraph data were downloaded and processed with ActiLife 6.13.3 software using 30 different techniques, summarized in Appendix Table B.1. Each participant's vertical axis and vector magnitude data were processed with two filters (normal, LFE) and three variations of the Choi non-wear algorithm (minimum lengths of 60, 90, 120 minutes). Two SB cut-points were applied to all vertical axis data (<1 count/15s (Evenson et al., 2015; Koster et al., 2016), <10 counts/15s (Aguilar-Farias et al., 2014)), three cut-points were applied to vector magnitude data with normal filter (<19 counts/15s (Evenson et al., 2015), <20 counts/15s (Koster et al., 2016), <70 counts/15s (Aguilar-Farias et al., 2014)), and three cut-points were applied to vector magnitude data with LFE filter (<20 counts/15s (Koster et al., 2016), <40 counts/15s (Evenson et al., 2015), <70 counts/15s (Aguilar-Farias et al., 2014)). These cut-points were selected because previous studies identified them as optimal for measuring SB in older adults (Aguilar-Farias et al., 2014; Evenson et al., 2015; Koster et al., 2016). Previously validated vertical axis cut-points were tested with vertical axis data and previously validated vector magnitude cut-points were tested with vector magnitude data. Evenson et al. developed different cut-points for normal vs. LFE filter and this is reflected in the techniques we tested. Koster et al. did not specify which filter was used in cut-point development, therefore we tested the Koster cut-points with both filters. Aguilar-Farias et al. cut-points were developed with the LFE filter, but to be thorough we also tested them with the normal filter. Data were analyzed using 15-second epochs.

ActiGraph data were processed with date/time filters to ensure the morning start and evening stop times were consistent across processing techniques. Waking hours were determined individually for each participant and each day by examining ActiGraph wear validation files for when the device was put on after waking for the day and taken off before going to bed. If the start or stop time was not clear for a particular processing technique, the time closest to the journal recorded waking or bedtime was used. If wear validation files showed different start/stop times across processing techniques for a participant on a particular day, we applied the shortest window of waking hours to all processing techniques (latest waking time and/or earliest bedtime).

The activPAL was applied to the right thigh with a waterproof dressing and participants were asked to wear it 24 hours/day, even during water activities. ActivPAL data were downloaded and processed with PAL Software version 7 to identify time spent sitting or lying (sedentary time). Using 15-second epoch files, the 24-hour activPAL data were trimmed to the same waking hours that were applied with the date/time filter for the ActiGraph.

Statistical analyses were conducted with Stata 15.1 software (StataCorp, 2017). Demographic characteristics are reported as means and standard deviations (SD). Concordance correlations and Bland-Altman plots were used to assess agreement between ActiGraph-measured sedentary time for each of the 30 data processing techniques and activPAL-measured sedentary time using individual day-level data. Bootstrapping standard errors were used to adjust for the nesting of observations (repeated measurements per days of the week) within experimental units (participants). Mean differences and 95% limits of agreement in sedentary time between the two devices are reported.

Results

Fifty-nine participants had adequate data for analysis, 31 men and 28 women with a mean age of 69.4 (SD 7.8). Forced expiratory volume (% predicted) ranged from 15-76% (mean 54.9, SD 15.7), indicating moderate to severe airflow obstruction. Participants contributed 377 valid days of activity monitoring, with a mean of 6.4 monitoring days per participant. Mean activPAL-measured sedentary time was 607.2 minutes/day (SD 145.6). Mean AG-measured sedentary times for the 30 processing techniques ranged from 515.9 (SD 126.0) to 658.2 (SD 124.7) minutes/day (Table 3.1). Concordance correlations, mean differences, and limits of agreements are presented in Table 3.2. The combination of vector magnitude data, LFE filter, 120-minute non-wear algorithm, and <40 counts/15s cut-point for SB resulted in the strongest concordance correlation for ActiGraph and activPAL-measured sedentary time (0.838, SE 0.015) and a small mean difference (-11.7 minutes/day, SD 77.9). The combination of vertical axis data, LFE filter, 60-minute non-wear algorithm, and cut-point of <10 counts/15s produced the smallest mean difference for ActiGraph and activPAL measured sedentary time (2.2 minutes/day, SD 91.5), but the concordance correlation was lower (0.766, SE 0.020). The combination of vertical axis data, LFE filter, 60-minute non-wear algorithm, and cut-point of <1 count/15s resulted in the weakest concordance correlation (0.614, SE 0.026) and the largest mean difference (-91.3 minutes/day, SD 95.8). Limits of agreement were wide for all comparisons.

Overall, ActiGraph vector magnitude techniques had stronger agreement with activPAL than vertical axis. For vector magnitude techniques, concordance correlations and mean differences were similar for the normal and LFE filters. With the normal filter, the lower cut-points (<19 counts/15s and <20 counts/15s) resulted in stronger correlations than the higher cut-point (<70 counts/15s). The middle cut-point (<40 counts/15s) was optimal with the LFE filter. Agreement was slightly stronger as the non-wear algorithm length increased.

With vertical axis data, concordance correlations were similar for both the normal and LFE filters. The lower cut-point (<1 count/15s) was optimal with the normal filter and the higher cut-point (<10 counts/15s) was optimal with the LFE filter. Concordance correlations were similar for the three non-wear algorithm lengths, but generally increased as algorithm length increased.

Bland-Altman plots for the vector magnitude and vertical axis comparisons with the strongest concordance correlations are presented in Figure 3.1. These plots show lines of mean difference that are close to the lines of perfect agreement. Additional Bland-Altman plots are in Appendix Figure B.1. Bland-Altman plots show fairly uniform distribution.

Discussion

This is the first known direct comparison of the ActiGraph and activPAL using vertical axis and vector magnitude hip-worn ActiGraph data with all combinations of normal and low frequency extension filters, three non-wear algorithms lengths, and multiple validated cut-points for measuring sedentary time. ActiGraph data processing criteria greatly impacted sedentary times estimates, consistent with previous work (Cleland et al., 2020). However, 17 of the 30 techniques resulted in mean differences <30 minutes/day above or below the activPAL estimate. Agreement between the two devices was moderate to strong for all processing techniques and concordance correlations were similar for several techniques. Processing ActiGraph sedentary time with vector magnitude data, LFE filter, 120-minute non-wear algorithm, and SB cut-point of <40 counts/15s resulted in the strongest agreement with activPAL sedentary time and a small mean difference between the devices.

Concordance correlations support the use of vector magnitude data. Vector magnitude techniques may be more precise in distinguishing sedentary behavior from either light PA or non-wear time than vertical axis acceleration data alone (Evenson et al., 2015). This is consistent with previous research using the ActiGraph GT3X+ device to measure SB in older adults; mean differences between ActiGraph and activPAL-measured SB were smaller when ActiGraph vector magnitude data were used compared to vertical axis data (Aguilar-Farias et al., 2014; Koster et al., 2016). This analysis strengthens the evidence that triaxial vector magnitude techniques improve the measurement of SB. However, the results suggest that vertical axis data may also provide acceptable measurement of SB if an appropriate cut-point and filter combination is utilized. Since most studies have historically analyzed vertical axis data, the vertical axis results may aid in interpretation of previous research.

Our analysis suggested that either the normal or LFE filter may be acceptable. The LFE filter has been recommended for use with vertical axis data to improve sensitivity to low intensity activity (ActiGraph; Cain et al., 2013), but it may not improve measurement with vector magnitude data (Evenson et al., 2015). The best overall combination of criteria in this analysis included the LFE filter, although some combinations using the normal filter performed similarly. The optimal filter varied depending on the cut-point for sedentary behavior. The LFE filter was favored in combination with higher cut-points, while the normal filter performed better with lower cut-points. Therefore, either filter may be acceptable if combined with an appropriate sedentary cut-point.

The cut-points tested in this analysis were selected from older adult validation studies to examine which were most valid in this sample of adults age ≥50 with COPD (Aguilar-Farias et al., 2014; Evenson et al., 2015; Koster et al., 2016). This analysis highlights four SB cut-points that may be optimal in this population depending on the other criteria: <1 count/15s (Evenson et al., 2015; Koster et al., 2016) (with vertical axis, normal filter), <10 counts/15s (Aguilar-Farias et al., 2014) (with vertical axis, LFE filter), <20 counts/15s (Koster et al., 2016) (with vector magnitude, normal filter), and <40 counts/15s (Evenson et al., 2015) (with vector magnitude, LFE filter).

The 120-minute non-wear algorithm consistently resulted in the strongest concordance correlations when other criteria were constant, but did not always result in the smallest mean difference, particularly for vertical axis techniques. For vector magnitude techniques, the 120-minute algorithm showed the strongest concordance correlations and smallest mean differences when using optimal filter and cut-point combinations. Two studies with older adults in free living environments found 90-minute non-wear algorithms were most accurate, but used different methodologies than the current study (Choi et al., 2012; Chudyk et al., 2017). Some studies that utilized different types of accelerometers have supported 120-minute non-wear algorithms (Hutto et al., 2013; King et al., 2011). Using a longer non-wear algorithm could reduce the risk of counting true SB as a non-wear period, but could also increase the risk of not identifying shorter periods of actual non-wear time (Knaier et al., 2019). A longer non-wear algorithm could therefore be more accurate in populations with prolonged sedentary bouts. More work is needed to confirm whether the 120-minute length is optimal in adults with chronic disease such as COPD.

The wide limits of agreement indicate that ActiGraph group-level estimates of SB are more accurate than individual-level estimates. The ActiGraph and activPAL comparisons that resulted in concordance correlations 0.800 or above consistently had small mean differences between the devices, <30 min/day, which are probably not clinically meaningful. Evidence suggests that decreasing sedentary time by 30 minutes/day may reduce mortality risk by 14% (Schmid et al., 2016). We also note that our trimming of data from both devices to the exact same waking hours likely resulted in higher congruence than if they were not matched in this way.

With appropriate processing techniques, the ActiGraph is an acceptable device for measuring SB. Specifically, this analysis shows that both types of data (vertical and vector magnitude) and both filters (normal and LFE) can be used to measure SB reasonably well if appropriate cut-points are utilized. This flexibility is helpful for researchers who are also interested in measuring PA and want to utilize cut-points for moderate or vigorous activity validated with a specific type of data and filter. For example, if a chosen data processing protocol for measuring moderate-to-vigorous PA requires the use of vector magnitude and the normal filter, our analysis could guide the selection of an appropriate SB cut-point.

This analysis had strengths and limitations. The activPAL is considered the most valid measure of SB in a free living environment and the use of this device is a major strength of the study. The comparison of multiple previously validated methods for data processing is another strength and this information can be used to facilitate the interpretation of previous research and guide decisions about processing data in future research. Limitations include a modest sample size and results that are not generalizable to other populations.

Conclusion

Processing ActiGraph data with vector magnitude data, LFE filter, 120-minute non-wear algorithm, and <40 counts/15s cut-point for SB resulted in sedentary time that most closely matched activPAL-measured sedentary time in adults with COPD. These results support the use of ActiGraph to measure SB if processing techniques are optimized by selecting appropriate cut-points based on the type of data (vertical or vector magnitude) and the chosen filter.

Table 3.1. Mean sedentary time results for each ActiGraph data processing technique (minutes/day).

Processing Technique (Type of Data, Filter, Non-Wear Algorithm Length, & Cut-Point)	Mean Sedentary Time (SD)	Processing Technique (Type of Data, Filter, Non-Wear Algorithm Length, & Cut-Point)	Mean Sedentary Time (SD)
Vertical Axis		Vector Magnitude	
Normal & 60 min.		Normal & 60 min.	
<1 count/15s	595.8 (113.1)	<19 counts/15s	571.8 (125.7)
<10 counts/15s	636.2 (112.2)	<20 counts/15s	574.3 (125.5)
Normal & 90 min.		<70 counts/15s	643.0 (121.0)
<1 count/15s	614.9 (117.7)	Normal & 90 min.	
<10 counts/15s	655.3 (116.2)	<19 counts/15s	581.6 (128.5)
Normal & 120 min.		<20 counts/15s	584.0 (128.4)
<1 count/15s	623.8 (120.7)	<70 counts/15s	652.7 (123.7)
<10 counts/15s	664.3 (118.9)	Normal & 120 min.	
LFE & 60 min.		<19 counts/15s	587.1 (129.9)
<1 count/15s	515.9 (126.0)	<20 counts/15s	589.6 (129.8)
<10 counts/15s	609.4 (120.6)	<70 counts/15s	658.2 (124.7)
LFE & 90 min.		LFE & 60 min.	
<1 count/15s	524.9 (128.5)	<20 counts/15s	542.7 (132.7)
<10 counts/15s	618.4 (123.1)	<40 counts/15s	586.8 (129.8)
LFE & 120 min.		<70 counts/15s	626.4 (126.7)
<1 count/15s	529.8 (128.9)	LFE & 90 min.	

Processing Technique (Type of Data, Filter, Non-Wear Algorithm Length, & Cut-Point)	Mean Sedentary Time (SD)	Processing Technique (Type of Data, Filter, Non-Wear Algorithm Length, & Cut-Point)	Mean Sedentary Time (SD)
<10 counts/15s	623.3 (123.1)	<20 counts/15s	547.6 (134.1)
		<40 counts/15s	591.8 (131.1)
		<70 counts/15s	631.3 (128.0)
		LFE & 120 min.	
		<20 counts/15s	551.3 (133.2)
		<40 counts/15s	595.5 (130.1)
		<70 counts/15s	635.0 (126.8)

Abbreviations: SD, standard deviation; LFE, low frequency extension filter

Table 3.2. Concordance correlations coefficients (SE), mean differences (SD), and limits of agreement between ActiGraph sedentary time for each processing technique and activPAL sedentary time.

Processing Technique (Type of Data, Filter, Non-Wear Algorithm Length, & Cut-Point)	Concordance Correlation (SE)	Mean Difference ActiGraph-activPAL (SD), minutes/day	95% Limits of Agreement, minutes/day
Vertical Axis			
Normal & 60 min.			
<1 count/15s	0.729 (0.023)	-11.4 (95.5)	-198.7, 175.8
<10 counts/15s	0.680 (0.025)	29.0 (101.1)	-169.2, 227.2
Normal & 90 min.			
<1 count/15s	0.753 (0.021)	7.6 (92.8)	-174.2, 189.4
<10 counts/15s	0.679 (0.025)	48.1 (97.8)	-143.6, 239.7
Normal & 120 min.			
<1 count/15s	0.774 (0.020)	16.6 (88.7)	-157.2, 190.4
<10 counts/15s	0.689 (0.024)	57.0 (93.5)	-126.2, 240.3
LFE & 60 min.			
<1 count/15s	0.614 (0.026)	-91.3 (95.8)	-279.1, 96.6
<10 counts/15s	0.766 (0.020)	2.2 (91.5)	-177.0, 181.5
LFE & 90 min.			
<1 count/15s	0.643 (0.025)	-82.3 (95.4)	-269.3, 104.7
<10 counts/15s	0.771 (0.020)	11.2 (90.8)	-166.7, 189.1
LFE & 120 min.			

Processing Technique (Type of Data, Filter, Non-Wear Algorithm Length, & Cut-Point)	Concordance Correlation (SE)	Mean Difference ActiGraph-activPAL (SD), minutes/day	95% Limits of Agreement, minutes/day
<1 count/15s	0.664 (0.025)	-77.5 (93.2)	-260.2, 105.3
<10 counts/15s	0.782 (0.019)	16.0 (87.8)	-156.1, 188.2
Vector Magnitude			
Normal & 60 min.			
<19 counts/15s	0.780 (0.019)	-35.4 (84.6)	-201.1, 130.4
<20 counts/15s	0.784 (0.019)	-32.9 (84.5)	-198.6, 132.8
<70 counts/15s	0.761 (0.020)	35.8 (87.1)	-134.8, 206.4
Normal & 90 min.			
<19 counts/15s	0.807 (0.017)	-25.6 (82.0)	-186.4, 135.2
<20 counts/15s	0.810 (0.017)	-23.2 (82.0)	-183.9, 137.5
<70 counts/15s	0.763 (0.020)	45.5 (84.2)	-119.4, 210.4
Normal & 120 min.			
<19 counts/15s	0.828 (0.016)	-20.1 (78.7)	-174.4, 134.2
<20 counts/15s	0.831 (0.016)	-17.7 (78.6)	-171.8, 136.5
<70 counts/15s	0.770 (0.019)	51.0 (80.2)	-106.2, 208.2
LFE & 60 min.			
<20 counts/15s	0.736 (0.021)	-64.5 (84.6)	-230.4, 101.3
<40 counts/15s	0.814 (0.017)	-20.4 (82.0)	-181.2, 140.4
<70 counts/15s	0.811 (0.017)	19.2 (82.2)	-141.9, 180.2

Processing Technique (Type of Data, Filter, Non-Wear Algorithm Length, & Cut-Point)	Concordance Correlation (SE)	Mean Difference ActiGraph-activPAL (SD), minutes/day	95% Limits of Agreement, minutes/day
LFE & 90 min.			
<20 counts/15s	0.756 (0.020)	-59.6 (82.8)	-221.9, 102.7
<40 counts/15s	0.828 (0.016)	-15.5 (80.1)	-172.5, 141.6
<70 counts/15s	0.816 (0.017)	24.1 (80.1)	-133.0, 181.1
LFE & 120 min.			
<20 counts/15s	0.770 (0.019)	-55.9 (80.9)	-214.4, 102.7
<40 counts/15s	0.838 (0.015)	-11.7 (77.9)	-164.4, 141.0
<70 counts/15s	0.821 (0.016)	27.8 (77.7)	-124.5, 180.2

Abbreviations: SE, standard error; SD, standard deviation; s, seconds; LFE, low frequency extension

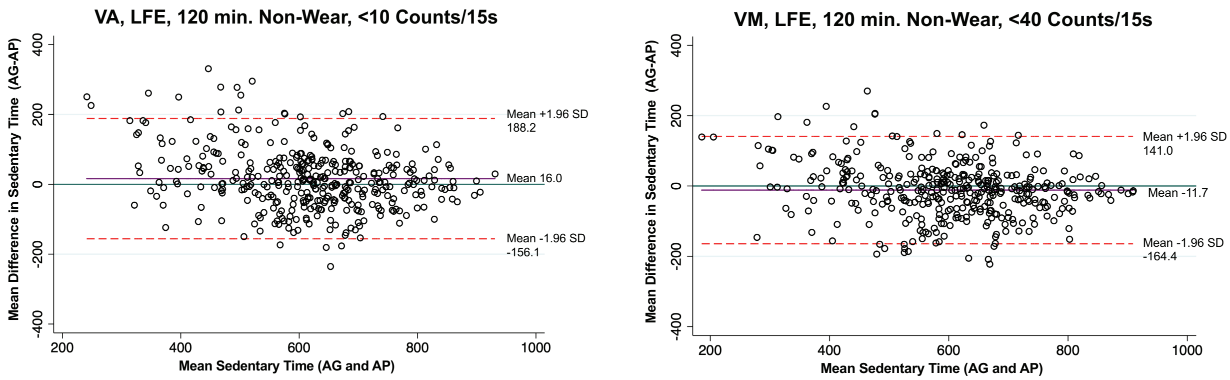

Figure 3.1. Bland-Altman Plots comparing sedentary time (waking minutes/day) measured by the ActiGraph and activPAL. These plots represent the ActiGraph vertical axis and vector magnitude methods with strongest concordance correlations.

Y=0 is the line of perfect average agreement. Solid lines represent mean difference. Dashed lines indicate 95% limits of agreement.

Abbreviations: AG, ActiGraph; AP, activPAL; LFE, low frequency extension filter; s, seconds; VA, vertical axis data; VM, vector magnitude data

References

ActiGraph. Low Frequency Extension Filter. Retrieved September 27, 2019, from https://s3.amazonaws.com/actigraphcorp.com/wp-content/uploads/2017/11/26205810/Low-Frequency-Extension-Filter.pdf

ActiGraph. (2019). User guide ActiGraph GT9X Link + ActiLife.

Aguilar-Farias, N., Brown, W. J., & Peeters, G. M. (2014). ActiGraph GT3X+ cut-points for identifying sedentary behaviour in older adults in free-living environments. *Journal of science and medicine in sport*, *17*(3), 293-299. https://doi.org/10.1016/j.jsams.2013.07.002 [doi]

Cain, K. L., Conway, T. L., Adams, M. A., Husak, L. E., & Sallis, J. F. (2013). Comparison of older and newer generations of ActiGraph accelerometers with the normal filter and the low frequency extension. *The international journal of behavioral nutrition and physical activity*, *10*(1), 51-51. https://doi.org/10.1186/1479-5868-10-51

Choi, L., Liu, Z., Matthews, C. E., & Buchowski, M. S. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Medicine and science in sports and exercise*, *43*(2), 357-364. https://doi.org/10.1249/MSS.0b013e3181ed61a3 [doi]

Choi, L., Ward, S. C., Schnelle, J. F., & Buchowski, M. S. (2012). Assessment of wear/nonwear time classification algorithms for triaxial accelerometer. *Medicine and science in sports and exercise*, *44*(10), 2009-2016. https://doi.org/10.1249/MSS.0b013e318258cb36

Chudyk, A. M., McAllister, M. M., Cheung, H. K., McKay, H. A., & Ashe, M. C. (2017). Are we missing the sitting? Agreement between accelerometer non-wear time validation methods used with older adults' data. *Cogent medicine*, *4*, 1313505. https://doi.org/10.1080/2331205X.2017.1313505 [doi]

Cleland, C. L., Ferguson, S., McCrorie, P., Schipperijn, J., Ellis, G., & Hunter, R. F. (2020). Considerations in Processing Accelerometry Data to Explore Physical Activity and Sedentary Time in Older Adults. *Journal of Aging & Physical Activity*, *28*(4), 623-633. https://doi.org/10.1123/japa.2019-0244

Evenson, K. R., Wen, F., Herring, A. H., Di, C., LaMonte, M. J., Tinker, L. F., Lee, I. M., Rillamas-Sun, E., LaCroix, A. Z., & Buchner, D. M. (2015). Calibrating physical activity intensity for hip-worn accelerometry in women age 60 to 91 years: The Women's Health Initiative OPACH Calibration Study. *Preventive Medicine Reports*, *2*(C), 750-756. https://doi.org/10.1016/j.pmedr.2015.08.021

Hanauer, D. A., Mei, Q., Law, J., Khanna, R., & Zheng, K. (2015). Supporting information retrieval from electronic health records: A report of University of Michigan's nine-year experience in developing and using the Electronic Medical Record Search Engine

(EMERSE). *Journal of biomedical informatics*, *55*, 290-300. https://doi.org/10.1016/j.jbi.2015.05.003

Hart, T. L., Swartz, A. M., Cashin, S. E., & Strath, S. J. (2011). How many days of monitoring predict physical activity and sedentary behaviour in older adults? *The international journal of behavioral nutrition and physical activity*, *8*, 62-5868-5868-5862. https://doi.org/10.1186/1479-5868-8-62 [doi]

Hutto, B., Howard, V. J., Blair, S. N., Colabianchi, N., Vena, J. E., Rhodes, D., & Hooker, S. P. (2013). Identifying accelerometer nonwear and wear time in older adults. *The international journal of behavioral nutrition and physical activity*, *10*, 120-5868-5810-5120. https://doi.org/10.1186/1479-5868-10-120 [doi]

Judice, P. B., Teixeira, L., Silva, A. M., & Sardinha, L. B. (2019). Accuracy of Actigraph inclinometer to classify free-living postures and motion in adults with overweight and obesity. *J Sports Sci*, *37*(15), 1708-1716. https://doi.org/10.1080/02640414.2019.1586281

Keadle, S. K., Shiroma, E. J., Freedson, P. S., & Lee, I. M. (2014). Impact of accelerometer data processing decisions on the sample size, wear time and physical activity level of a large cohort study. *BMC Public Health*, *14*(1), 1210-1210. https://doi.org/10.1186/1471-2458-14-1210

Kelly, L. A., McMillan, D. G. E., Anderson, A., Fippinger, M., Fillerup, G., & Rider, J. (2013). Validity of actigraphs uniaxial and triaxial accelerometers for assessment of physical activity in adults in laboratory conditions. *BMC medical physics*, *13*(1), 5-5. https://doi.org/10.1186/1756-6649-13-5

King, W. C., Li, J., Leishear, K., Mitchell, J. E., & Belle, S. H. (2011). Determining Activity Monitor Wear Time: An Influential Decision Rule. *Journal of Physical Activity and Health*, *8*(4), 566-580. https://doi.org/10.1123/jpah.8.4.566

Knaier, R., Höchsmann, C., Infanger, D., Hinrichs, T., & Schmidt-Trucksäss, A. (2019). Validation of automatic wear-time detection algorithms in a free-living setting of wrist-worn and hip-worn ActiGraph GT3X. *BMC Public Health*, *19*(1), 244-244. https://doi.org/10.1186/s12889-019-6568-9

Koster, A., Shiroma, E. J., Caserotti, P., Matthews, C. E., Chen, K. Y., Glynn, N. W., & Harris, T. B. (2016). Comparison of sedentary estimates between ActivPAL and hip- and wrist-worn ActiGraph. *Medicine and science in sports and exercise*, *48*(8), 1514-1522. https://doi.org/10.1249/MSS.0000000000000924 [doi]

Kozey-Keadle, S., Libertine, A., Lyden, K., Staudenmayer, J., & Freedson, P. S. (2011). Validation of wearable monitors for assessing sedentary behavior. *Medicine and science in sports and exercise*, *43*(8), 1561-1567. https://doi.org/10.1249/MSS.0b013e31820ce174 [doi]

Larson, J. L., Covey, M. K., Kapella, M. C., Alex, C. G., & McAuley, E. (2014). Self-efficacy enhancing intervention increases light physical activity in people with chronic obstructive pulmonary disease. *International journal of chronic obstructive pulmonary disease*, *9*, 1081-1090. https://doi.org/10.2147/COPD.S66846 [doi]

Mailey, E. L., Gothe, N. P., WÃ³jcicki, T. R., Szabo, A. N., Olson, E. A., Mullen, S. P., Fanning, J. T., Motl, R. W., & McAuley, E. (2014). Influence of Allowable Interruption Period on Estimates of Accelerometer Wear Time and Sedentary Time in Older Adults. *Journal of Aging and Physical Activity*, *22*(2), 255-260. http://proxy.lib.umich.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=gnh&AN=EP95065529&site=ehost-live&scope=site

Migueles, J., Cadenas-Sanchez, C., Ekelund, U., Delisle NystrÃ¶m, C., Mora-Gonzalez, J., LÃ¶f, M., Labayen, I., Ruiz, J., & Ortega, F. (2017). Accelerometer Data Collection and Processing Criteria to Assess Physical Activity and Other Outcomes: A Systematic Review and Practical Considerations. *Sports Medicine*, *47*(9), 1821-1845. https://doi.org/10.1007/s40279-017-0716-0

Reid, N., Eakin, E., Henwood, T., Keogh, J. W. L., Senior, H. E., Gardiner, P. A., Winkler, E., & Healy, G. N. (2013). Objectively measured activity patterns among adults in residential aged care. *International Journal of Environmental Research and Public Health*, *10*(12), 6783-6798. https://doi.org/10.3390/ijerph10126783

Sasaki, J. E., John, D., & Freedson, P. S. (2011). Validation and comparison of ActiGraph activity monitors. *Journal of science and medicine in sport*, *14*(5), 411-416. https://doi.org/10.1016/j.jsams.2011.04.003

Schmid, D., Ricci, C., Baumeister, S. E., & Leitzmann, M. F. (2016). Replacing Sedentary Time with Physical Activity in Relation to Mortality. *Medicine and science in sports and exercise*, *48*(7), 1312-1319. https://doi.org/10.1249/MSS.0000000000000913 [doi]

StataCorp. (2017). *Stata Statistical Software: Release 15*. In StataCorp LLC.

Taraldsen, K., Askim, T., Sletvold, O., Einarsen, E. K., Bjåstad, K. G., Indredavik, B., & Helbostad, J. L. (2011). Evaluation of a Body-Worn Sensor System to Measure Physical Activity in Older People With Impaired Function. *Physical Therapy*, *91*(2), 277-285. https://doi.org/10.2522/ptj.20100159

Wallén, M. B., Nero, H., Franzén, E., & Hagströmer, M. (2014). Comparison of two accelerometer filter settings in individuals with Parkinson's disease. *Physiological Measurement*, *35*(11), 2287-2296. https://doi.org/10.1088/0967-3334/35/11/2287

Wanner, M., Martin, B. W., Meier, F., Probst-Hensch, N., & Kriemler, S. (2013). Effects of filter choice in GT3X accelerometer assessments of free-living activity. *Medicine and science* *in sports and exercise*, *45*(1), 170-177. https://doi.org/10.1249/MSS.0b013e31826c2cf1 [doi]

CHAPTER IV

(Paper 3)

Qualitative Feedback from Assisted Living Residents on a Proposed Intervention for Reducing Sedentary Behavior

Abstract

Replacing sedentary behavior (SB) with light physical activity (LPA) could promote maintenance of functional abilities for older adults in assisted living (AL). The purpose of this qualitative study was to gather feedback from AL residents on a self-efficacy enhancing intervention (Active for Life) to promote LPA. We conducted one-on-one interviews with 20 residents (mean age 83.1; 60% women). We presented the intervention to them and asked questions to inform its modification. Data were analyzed with content and thematic analysis. Residents overall liked the proposed intervention and were interested in participating. Specific recommendations included a shorter intervention length, shorter sessions, and framing the intervention message as increasing LPA rather than decreasing SB. The thematic analysis identified multiple factors that could influence intervention implementation, including motivation, safety, beliefs about aging, varying abilities, social influences, and physical activity opportunities in AL. Residents provided useful feedback for refining the Active for Life intervention.

Background

Older adults in assisted living (AL) tend to be highly sedentary, which may adversely impact their health and function (Manas et al., 2017; Taylor et al., 2020; Vos, 2017). Sedentary behavior increases the risk for frailty, decline in physical function, and mortality (Grgic et al., 2018; Manas et al., 2017; Manãs et al., 2019). Cognitive and mental health are also adversely affected by high levels of sedentary behavior (Park et al., 2017; Rojer et al., 2021). In contrast, light physical activity may positively impact physical function, cognitive function, and life expectancy (Del Pozo Cruz et al., 2021; Erlenbach et al., 2021; Fanning et al., 2020). Maintaining physical function will help AL residents remain as independent as possible and prevent or delay the need for higher levels of assistance, including transfer to higher level care facilities such as nursing homes (Giuliani et al., 2008). Therefore, interventions to replace sedentary behavior with light physical activities could have important implications for quality of life in this population.

The AL environment may limit the physical activity levels of residents as staff often perform daily activities (such as housekeeping), even if residents have the ability to perform them (Resnick et al., 2011). Assisted living facilities often provide chair exercise classes (Mihalko & Wickley, 2003), but these classes are not evidence-based and do not address sedentary behavior. The AL social environment provides a unique opportunity for physical activity behavior change as residents interact closely with staff and one another (Mihalko & Wickley, 2003).

There has been limited research focused on interventions to decrease sedentary behavior of AL residents; we are aware of only three previous pilot interventions (Dillon & Prapavessis, 2020; Naber et al., 2020; Voss, Pope, Larouche, et al., 2020). The Voss et al. intervention utilized strategies at various levels of the ecological model and was found to be feasible, but the pilot trial did not decrease device-measured sedentary time (Voss, Pope, Larouche, et al., 2020). Naber et al. conducted an occupational therapy intervention to decrease sedentary behavior through individualized goal setting (Naber et al., 2020). Residents in that study had a non-significant increase in daily step counts, but did not decrease self-reported sedentary behavior. Finally, a pilot intervention by Dillon & Prapavessis aimed to decrease sedentary behavior through prompting 10 minutes of light physical activity three times per day (Dillon & Prapavessis, 2020). They found that intervention participants increased their physical activity, but included only residents with mild and moderate cognitive impairment; it is unknown how the intervention would generalize to AL residents broadly.

There is also little known about the preferences of AL residents related to physical activity programs. It is important that physical activity interventions be tailored for specific populations and one strategy to enhance tailoring is to engage stakeholders from the population of interest. This will help to ensure the intervention will be acceptable and will address their needs (Fernandez et al., 2019).

The Active for Life intervention is a physical activity-specific self-efficacy enhancing intervention designed to promote light physical activity and reduce sedentary behavior. It has been tested through multiple randomized controlled trials and was effective in other older adult populations for breaking up sedentary time, increasing light physical activity, and improving physical function (Fanning et al., 2016; Larson et al., 2014; McAuley et al., 2013). We made modifications to the Active for Life intervention so that it will be more appropriate for the AL population. The purpose of this study was to gather feedback from AL residents on the proposed intervention, Active for Life in Assisted Living. A secondary aim was to explore contextual factors that may influence how the intervention will be implemented with this population.

Methods

This study utilized qualitative methods and was designed to answer the primary research question, "What do AL residents think about the Active for Life in Assisted Living intervention and what suggestions do they have for its modification?" We used a content analysis approach to answer this question. We asked additional contextual questions in the interviews related to factors that could influence intervention implementation and analyzed this data using thematic analysis as a secondary approach.

This study was reviewed by the appropriate institutional review board and determined to be exempt from oversight. We recruited participants from four AL facilities. At three of the facilities, we advertised an informational meeting about the study to the residents through flyers and/or posted signs with the assistance of the life enrichment director at each facility. At the informational meetings, residents were given details about the nature of the study and had an opportunity to ask questions. If residents wished to participate in the study or meet with the researcher to ask additional questions, they could provide their contact information. At one AL facility, staff preferred that informational flyers with the researcher's contact information be distributed to each resident individually, rather than conducting an informational meeting. The sample size was determined by data saturation.

Inclusion criteria were age ≥65, being able to engage in activity without the use of a wheelchair or motorized scooter, not currently meeting physical activity guidelines (<150 minutes of moderate physical activity per week), and score ≥3 on the Mini-Cog screening.

Scores on the Mini-Cog range from 0-5 and a score <3 indicates cognitive impairment (Milian et al., 2012).

One-on-one semi-structured interviews were conducted using a two-part interview guide, which can be found in Appendix Table C.1. In part one, residents were asked questions about their daily lives in the AL facility, their current activities, and their general thoughts about physical activity. In part two, we presented the Active for Life in Assisted Living intervention to participants and requested feedback on each component of the intervention, their overall interest in participating, and any general suggestions for modifying the intervention. We also asked a few practical questions that could influence how intervention sessions are structured, such as how long they are able to stand and how far they are able to walk. Three questions on the interview guide were added later in the study after it became clear that they were important, and therefore they were not asked to all participants.

The interview included demographic data, length of stay in AL, use of assistive device, and completion of the Functional Comorbidity Index. The 18-item Functional Comorbidity Index is a stronger predictor of physical function than other comorbidity indices (Groll et al., 2005). Participants' scores can range 0-18 and are based on the number of comorbidities that they report. Reliability is supported by intraclass correlations of 0.90 for intra-rater reliability and 0.61 for inter-rater reliability (Kabboord et al., 2019).

Interviews were recorded and transcribed verbatim. K.W. analyzed interview transcripts using Atlas.ti software (ATLAS.ti, 2018). We chose content analysis to answer the primary research question because it allowed us to systematically code answers to specific questions about the proposed intervention and utilize counts in our descriptions of results (Elo & Kyngäs, 2008). A categorization matrix was developed to represent the specific interview topics we were interested in analyzing. We coded data according to the categorization matrix and summarized and counted responses within each category.

We chose thematic analysis as a secondary approach because it allowed us to identify patterns within the data related to contextual factors. We conducted this analysis according to the steps outlined by Braun & Clarke (Braun & Clarke, 2006). We reviewed all transcripts again for this secondary analysis. Briefly, this process included generating initial codes, searching for themes, reviewing themes, and defining/naming themes.

To check the validity of the findings, another researcher (N.G.) audited five interview transcripts and verified that the content and thematic analysis results were a good fit with the data.

Proposed Intervention

The proposed intervention utilizes theory-based strategies to enhance self-efficacy for physical activity. It consists of 16 weeks of physical activity sessions held twice per week in the facility, each lasting one and a half to two hours. Each session consists of 5-10 minutes of walking where participants are encouraged to walk at their own pace and take breaks as needed; 20-30 minutes of behavioral/educational activities designed to promote physical activity in their daily lives such as education on the benefits of light physical activity and the negative effects of sedentary behavior, goal setting, strategies for being active, and discussions about overcoming barriers to being active; and 30-45 minutes of circuit training with various exercise stations focusing on strength and balance, followed by stretching. After the first 15 interviews, it became clear that most residents felt the length of each session and the total intervention length were too long. The last five participants were asked for feedback on shorter intervention sessions of one to one and a half hours and a shorter 12-week intervention.

Results

Twenty-six AL residents expressed interest in participating and 20 were subsequently enrolled and interviewed. Of the residents who expressed interest but did not participate, two later decided they were not interested, two could not be contacted to schedule the interview, one was unavailable due to hospitalization, and one was ineligible due to age. Five participants were recruited from each facility. The number of apartment units at each facility ranged from 80-130.

The mean age of study participants was 83.1 (SD 9.8; range 65-99) with 60% (n=12) women, 85% (n=17) non-Hispanic White and 15% (n=3) non-Hispanic Black. The mean length of stay in AL was 41.4 months (SD 35.2) and participants had a mean score of 4.5 (SD 2.3) on the Functional Comorbidity Scale. All residents scored between 3-5 on the Mini-Cog screening. Forty percent (n=8) used a walker, 20% (n=4) used a cane, 15% (n=3) used both a cane and walker, and 25% (n=5) did not use an assistive device. The mean interview length was 48 minutes (range 18-81 minutes).

Content analysis

Assisted living residents provided feedback on several components of the proposed Active for Life intervention. Full results of the content analysis are in Table 4.1. Residents generally thought the three main intervention components (walking, educational/behavioral activities, and circuit training) sounded reasonable and helpful. Some residents remarked that the walking and circuit training would be appropriate for themselves, but might be challenging for other residents. Many residents thought a 16 week intervention was too long and the length of 12 week presented to the final 5 participants was better received. However, four residents additionally commented that regardless of the length, residents will not be accustomed to a program where they are asked to regularly attend, as activities in their facility are typically optional. Residents generally thought 1.5-2 hour sessions were too long, with three residents mentioning that they are accustomed to activities in their facility lasting ≤1 hour.

Most residents were interested in participating in the proposed intervention (n=13) or expressed that they would try it (n=5), although one resident thought her physical activity was sufficient without the program and another was not at all interested in physical activity. They expressed that interest in participating will likely vary among residents (n=8), with two residents commenting that others will probably like the intervention if it is enjoyable and they can see its benefits. Others suggested that recruitment will be challenging (n=5), but that participation could be improved with incentives and something "catchy" to get them interested (n=2). For framing the goals of the intervention, twelve residents felt that emphasizing increasing light physical activity by 30 minutes would be more motivating than focusing on decreasing sedentary behavior, mainly because it sounds more positive.

Thematic analysis

We identified seven themes and nine sub-themes related to factors that could be important in implementation of an intervention to promote physical activity with the AL population (Table 4.2).

Attitudes and Beliefs about Physical Activity

The first theme, attitudes and beliefs about physical activity includes three sub-themes.

Significance of Physical Activity. Assisted living residents predominantly believed that physical activity is very important and has a number of potential benefits for them. As one resident commented, "*It's very important. Extremely. Because I don't want people have to take care of me. It maintains my independence…and I know how important it is because I'm not as strong as I once was, and I know it's from sitting (02).*" In addition to the ability to move and maintain independence, residents associated physical activity with beneficial outcomes such as weight loss, pain reduction, and maintenance of mental capabilities and mental health. Contrary to most AL residents, one resident did not believe physical activity was valuable at his age.

Motivation and Confidence for Physical Activity. Assisted living residents described that low motivation or self-described "laziness" could hinder their activity levels, even if they wanted to be active. One resident described a conversation with herself about her motivation to be active: "*I says, 'Self, get up and go for a walk…' But I haven't done it yet (02)*." Residents expressed that confidence in their ability to be physically active was important and that other residents may need help building their confidence for physical activity: "*They need the encouragement to get their confidence, because they're capable of doing it. They just have been told so long that, 'You're old (10)*.'"

Safety Concerns. Residents expressed safety concerns about balance, falls, and injury risks during physical activity. Some had fallen in the past and were conscious of avoiding future falls, like one resident who said, "*So I don't want to fall No. So it's…You've got to think safety all the time.(06)*" Concerns about levels of supervision and monitoring while they perform physical activity were common. In thinking about physical activity sessions, one resident was concerned for other residents in her facility and said, "*You don't want anybody to have an accident and get hurt…they're going to need people helping so that nobody gets into trouble (05)*."

Attitudes and Beliefs about Aging

This theme represented how AL residents think and feel about aging and the relationship between aging and physical activity. Two sub-themes will be described next.

Perspectives on Aging. A few AL residents expressed that they don't feel society values older people. As one resident said, "*Nobody is positive about senior citizens except senior citizens…People throw away, have a tendency to throw away, old folks, and we still got some life in us, so they need to stop throwing us away (10)*." Some residents described a personal discouragement related to aging and not being able to do as much as they used to do. As one resident said, "*People don't realize, I don't think, how devastating getting old is (18)*." On the other hand, many residents were thankful that they still maintained certain abilities at their age: "*And I just feel very fortunate. When I look around I think I'm 80 years old and I'm still walking, thank God (07)*."

Appropriate Level of Physical Activity in Older Age. Residents discussed how much physical activity they should be doing in their older age. They acknowledged that their activities had changed as they aged: "*I'm getting old and I can't do what I did before. But I had fun doing it (07)*." Several talked about the tendency they have to "baby" themselves or not push themselves in their physical activity as they get older. There seemed to be some uncertainty about how much physical activity they should be doing and whether too much could be harmful, as evidenced by one resident who shared, "*I'm concerned that I will decondition. I feel I have already and I want to maintain as much endurance but I don't know what reality is because my age is progressing. I've here lived a year longer, and so how much would I have deconditioned even if I was working really hard at home with a lot of outside work? Maybe I could be worse because I would be wearing my body out. I don't know (05)*."

Abilities of Assisted Living Residents

Another theme was related to how AL resident view their own physical and mental limitations and limitations of other residents. We identified two sub-themes.

Physical and Mental Limitations. Assisted living residents described a number of physical symptoms they experienced, including worsening eyesight, joint and back pain, fatigue, shortness of breath, dizziness, and balance issues. At times, these issues interfered with their ability to perform physical activities. Many of the residents interviewed also observed mobility limitations in other residents that they felt would limit those residents' abilities to exercise. As one said, "*Surprisingly, there is not too many in here that can get up and walk around in the place (12)*." They also recognized that different types of conditions might have different effects on physical activity: "*And so I guess the person themselves would have to decide if it's something they can do if they try because some things are temporary, and some are permanent disabilities (06)*." In addition to physical limitations, AL residents mentioned that many residents in their facility had some level of cognitive decline and that cognitive issues could be a barrier to participation in physical activity programs. In speaking about physical activity, on resident said, "*I just don't think most of them can stay focused on it (14)*."

Wide Range of Abilities. Related to physical and mental abilities, residents emphasized that there is a wide range of abilities among the residents in their facilities and that everyone is different. One resident described the different walking abilities: "*We have the walk—people that can walk real good and people that can walk a little bit and those that have the walkers (6)*." As a result of these varying abilities, residents expressed that it may be challenging to plan a single program that would be an appropriate level of difficulty for all residents: "*You're not going to get all of them in the same program. So you're going to have to pick…You're going to have people maybe like me that sit down this end. Then you're going to have people in electric carts up at this end, and they're not all going to fit your program (9)*." They also thought the program would need to be adjusted on an individual basis.

Social influences for physical activity

Two sub-themes were identified related to social factors that may be important to consider in planning a physical activity intervention.

Encouragement to be Physically Active. Some residents had family members who encouraged them to be more active. One said, "*My daughter…she totally encourages me to get active here constantly. 'Dad, you know, don't just sit in your room doing nothing. Get active and do things,' which I do (04)*." In some cases, family members discouraged them from doing certain activities due to safety concerns, like one resident's family who discouraged her from taking walks in the park due to her history of falls. Generally, the only form of encouragement from AL staff was to encourage them to attend chair exercise classes. Some said that physical activity was a conversation topic among residents and that they checked in with one another to see if they have done their walking. For example, one resident shared, "*Well, we all talk about, 'Did you take your walk today?'…and it's easy to walk when you've got other people that are interested, and those that aren't interested, you don't talk about it (09)*." They also invited one another to go for walks or encouraged one another to attend chair exercise classes. Some were inspired when they saw other residents being active. One resident described a conversation with herself: "*I say, 'If that man who recently had a stroke and he's walk—' I said, 'Now if he can do it, you can do it*.' (02)" On the other hand, some residents who felt they were the most active did not find encouragement from other residents.

Group Exercise Preference. When talking about their experiences in exercise classes, many residents commented that they really enjoyed group exercise settings. They liked the interaction, camaraderie, and encouragement found in group exercise. One described her experience with group exercise within the facility: "*Activity's more fun if you're doing it with* *people than—and see, I was alone in [US state] and didn't do as much as I am here, so it's fun to do it with other people (10)*." Another resident described why she liked group exercise classes based on experiences outside of the facility: "*Because you can encourage one another, and that type of stuff. And especially if you're having one of those achy days, and you really don't want to, but you see other people doing it, it kind of makes you do it too (19)."*

Space for being active

Residents commented that there was space available for walking near or around their facilities, however, safety concerns such as unpaved and uneven outdoor paths or uncertainty about the safety of surrounding neighborhoods led some to prefer walking within the facility. At three of the facilities, residents described exercise or therapy rooms but generally felt they were underutilized. They described barriers to using exercise rooms such as being unsure of how to use equipment or whether they needed physician permission or supervision: "*I didn't know what was expected of us and what was readily available to us or what would be okay for us to just, can you just go over and use that or does somebody have to be there, too, to oversee it or whatever and where is it? (05)*." At the facility without an exercise room, one resident commented on the space available for doing exercises: "*Well, there really isn't enough, and you do it in your room. And I got one of the smallest rooms here. (12)*."

Current Exercise Classes Offered

Residents described the types of exercise classes offered within their facilities, which were mainly chair exercises. Residents at a couple facilities also mentioned a walking club. A few residents regularly attended the chair exercise classes and felt they were valuable and beneficial. One resident remarked about the classes, "*I like that they keep us active. That they keep us not just doing nothing (04)*." However, most residents interviewed did not feel the classes were beneficial for them and while some still attended for the social aspect, many did not participate. Residents' descriptions of chair exercise classes included the following: "*You know, wish we had more activities in terms of physical activities, but the ones they have are so childish that a lot of people just don't participate because they are childish (14)*." Many felt that these classes were boring and didn't count as exercise: "*If you're sitting, that's not activity (16)*." Even at the facilities where a walking club was offered, the residents interviewed did not participate. As one resident described, "*I've seen them walking, and I would walk with them if I was available, but they walk very slow. And a number of them are using walkers or scooters and I think it's wonderful that they're doing it but it wouldn't provide me with the level of activity I felt like I was needing (03)*." They recognized that the classes were designed to be inclusive for everyone within the facility, including those who used wheelchairs, and that the classes could be beneficial for some residents. Even so, some wished the facility would offer classes that were more "*aggressive (04)*" and focused on promoting activity for those who were not using wheelchairs.

Limited Opportunities for Physical Activity

The nature of the AL environment contributed to a limited availability of opportunities for physical activity, such as when staff completes housekeeping tasks automatically: "*Don't need to do any of those things. They do it all for us. They don't even ask if we want to do it ourselves (04)*." Residents typically had less space for being active than they did before moving into AL and some had to leave exercise equipment behind when they moved. As one resident commented, "*When you leave a house that you're living in and have much more to do and everything, you're moving much more than what you are in any type of living, assisting living (03)*." Some residents mentioned that their physical activity was influenced by which days exercise classes were offered and that no classes were offered on weekends. One resident described his struggles with finding good times to go walking outside of the facility: "*But it always seems like if I go now I'm going to miss lunch. If I go now, I'm going to miss something, and there's short of a draw to be here at the right times (09)*." In some facilities, residents were bothered by the fact that there were no staircases to practice using the stairs in order to maintain that ability. Residents felt they had too much time for sedentary activities like watching television and wished more physical activities were available. One resident remarked that "*I feel like I have more energy than I have activity to express it (05).*"

Discussion

The results of both the content and thematic analyses are useful in planning an intervention to promote light physical activity and reduce sedentary behavior among AL residents. From the content analysis we found that residents preferred a shorter overall intervention length, shorter sessions, and framing the goal of the intervention in terms of increasing light physical activity. Residents overall liked the plan for the three components of the intervention (walking, behavioral activities, and circuit training) and most were interested in participating. The thematic analysis drew attention to a number of factors that could influence the implementation of physical activity interventions with the AL population including motivation, safety, beliefs about aging, varying abilities, and social influences.

We received a lot of pragmatic feedback from residents to inform the Active for Life in Assisted Living Intervention. Our findings are consistent with post-intervention feedback on a similar intervention with community-dwelling adults with COPD, where participants found the intervention components to be acceptable and were especially motivated by goal setting and self-monitoring using a pedometer (Larson & Webster, 2020). Preferences of AL residents in the current study related to framing the goals of the intervention suggested that telling residents to stop doing certain sedentary activities may be poorly received, consistent with evidence that residents only view certain types of sedentary activities negatively and emphasizing breaks in sedentary time may be more successful (Voss, Pope, & Copeland, 2020).

Attitudes and beliefs about physical activity identified in the thematic analysis were consistent with previous research. Other studies have reported that AL residents are aware that too much sedentary behavior or not enough physical activity can negatively affect physical and mental health (Kotlarczyk et al., 2020; Phillips & Flesner, 2013; Vos et al., 2019; Voss, Pope, & Copeland, 2020) and that lack of motivation (Phillips & Flesner, 2013; Voss, Pope, & Copeland, 2020), self-efficacy (Chen et al., 2015), and safety concerns are important (Kotlarczyk et al., 2020; Voss, Pope, & Copeland, 2020).

Our results reflect ageism and negative stereotypes related to aging that are highly prevalent in Western cultures (Dionigi, 2015). Because these stereotypes may be internalized by older adults and influence how they view themselves and their behaviors, it is not surprising that AL residents may not feel valued by society and may experience discouragement related to aging (Dionigi, 2015). Assisted living residents may believe increased sedentary behavior is an inevitable part of aging (Kotlarczyk et al., 2020; Voss, Pope, & Copeland, 2020), likely related to aging stereotypes of poor physical functioning and dependency (Dionigi, 2015).

The influence of AL residents' abilities echoed the findings of earlier work; physical conditions such as fatigue, mobility, pain, impaired sight and hearing, musculoskeletal problems, neurological conditions, and poor balance can impact residents' physical activity (Phillips & Flesner, 2013; Vos et al., 2019; Voss, Pope, & Copeland, 2020). The wide range of physical and mental abilities among AL residents discussed by participants in our study may be due to facilities moving toward an aging in place approach where residents with more complex care needs are staying in AL longer rather than transferring (Morgan et al., 2014).

Our results indicate that social influences on physical activity are meaningful to AL residents. Social engagement, such as through group physical activities, may motivate AL residents to reduce their sedentary behavior (Voss, Pope, & Copeland, 2020). Walking companions or walking groups may be helpful strategies to provide social support (Kotlarczyk et al., 2020), although residents in our study did not favor larger walking groups. Receiving encouragement from family or AL staff can motivate residents to reduce sedentary time and take walks (Phillips & Flesner, 2013; Voss, Pope, & Copeland, 2020). On the other hand, family members may discourage their AL resident from performing certain activities they perceive to be unsafe (Vos et al., 2019).

Residents reinforced the fact that structural factors have a major impact, specifically environmental and policy factors. Space available for being active, such as walking areas and dedicated exercise space and equipment, influences the physical activity of AL residents and requirements for physician permission or supervision are a barrier to residents using exercise space (Kotlarczyk et al., 2020; Phillips & Flesner, 2013). Services provided in AL for activities of daily living and household activities give them fewer reasons to move (Kotlarczyk et al., 2020; Voss, Pope, & Copeland, 2020). Residents' dissatisfaction with chair exercise classes and desire for more challenging programs are not surprising given that activities in AL are usually planned according to the "lowest common denominator" of physical and cognitive abilities (Morgan et al., 2014). Assisted living residents desire workouts tailored to their individual needs and abilities, including more vigorous exercises (Bender et al., 2021).

Our results have several implications for planning physical activity interventions in AL. Interventions could address issues of residents' motivation and confidence for physical activity (such as the self-efficacy enhancing strategies in our proposed intervention) and need to consider safety issues such as adequate supervision and appropriate supports and modifications to accommodate varying levels of ability. An intervention could help older adults in AL identify activities to remain engaged and active as they age and incorporate social support from family or other residents. The dissatisfaction of many residents with chair exercise classes highlights a need for other types of physical activity programs in AL that would be more beneficial for them.

There were strengths and limitations to this study. This study uniquely asked for feedback from AL residents on a proposed intervention to reduce sedentary behavior and this method of engaging the residents as stakeholders was a strength. In addition, residents provided rich data that allowed us to conduct a secondary analysis. Regarding limitations, the four AL facilities from which residents were recruited were fairly similar in the types of supports provided and activities offered. Based on comments made by several of the residents we interviewed, it is possible that the residents who volunteered for our study tended to be more active and have higher levels of physical function than others in their facilities. There are likely additional contextual factors that are important that we did not ask about and that did not come up in interviews.

Conclusion

The feedback from AL residents was very helpful in planning an intervention to reduce sedentary behavior and promote light physical activity. They recommended shortening each session and that the intervention emphasize increasing physical activity rather than decreasing sedentary behavior. We identified other important considerations in intervention planning, such as safety, accommodations for a wide range of abilities, social influences, and the unique AL environment. Residents could benefit from assistance in identifying opportunities for increasing physical activity, such as performing more household activities for themselves to the extent they are able to do so.

Table 4.1. Content analysis results on subjects' preferences and feedback related to the proposed intervention.

Interview topic	Main Responses	Other responses
<u>Walking</u> 5-10 minutes of walking at their own pace	• Walking is reasonable n=9 • Reasonable for others, I could do more n=4 • Reasonable for me, may be challenging for others n=3 • Walking time could be longer n=2	• Walking should be progressive in nature (build up the time) n=3 • Residents will have varying abilities n=3 • We (researchers) should consider residents' attention spans n=2 • We need to consider the space available for walking n=2 • "I'm more capable than most" n=2
<u>Behavioral/Educational Component</u> 20-30 minutes of education including the benefits of light physical activity, discussions about overcoming barriers to being active, and goal setting	• Good/helpful n=19	• We should shorten the time of this component n=5 • Need to address their confidence and motivation n=2 • Need to get to know the people n=2 • This is the less exciting component of the program n=2 • We should consider residents' attention spans n=1 • Not sure if most residents are interested in PA n=1 • Likes the idea of group discussions n=1 • We should phase out education over time n=1 • This component should not be between walking and circuit training n=1
<u>Circuit Training</u> 30-45 minutes with exercise stations focusing on strength and balance	• Good/helpful n=19 (but might be too challenging for some n=2) • Not interested n=1	• Residents will have varying abilities n=4 • Circuit training will be a helpful opportunity for things I can't or don't do on own n=3 • Supervision will be important n=3 • Some already exercise on their own (will they want to do more?) n=2 • Circuit training should be progressive in nature n=2 • Circuit training time should be shortened n=2 • We should stretch first n=2

		• May need two groups with different levels (such as a sitting exercise group and a standing exercise group) n=2 • We will need to figure out space where this would take place n=1 • Sounds good if people will join n=1 • Some residents may need modifications n=1 • Should not be mandatory (program in general) n=1 • Will need balance support n=1 • Have plan in place for if someone wanders off during exercise n=1
<u>Program Length</u> 16 weeks (n=15) 12 weeks (presented to final n=5)	<u>Presented 16 week</u> • Good length n=7 • Too long n=4 • Good for me, might be too long for others n=3 <u>Presented 12 week</u> • Good if…n=3 -we have the option to drop out -people interested enough to attend regularly (they are used to optional activities) -framed as "we're available to help you for 12 weeks", not that you have to attend for 12 weeks • Good length n=1 • Too long n=1	• It may take some time for people to ease into the program/they may join gradually n=4 • People are not used to programs where they would be expected to attend every session n=4 • Whether length is appropriate will depend on resident interest n=3 • Consider weather (some residents have to walk to main building) n=1 • Greater frequency for fewer weeks would be better n=1 • Most programs in assisted living are ongoing n=1 • Needs to be long enough to demonstrate value n=1
<u>Session Length</u>[a] 1.5-2 hours (n=15) 1-1.5 hours (n=5)	• 1.5-2 hours is too long n=8 (n=3 said sessions should be 1 hour only) • 1.5-2 hours is appropriate n=2	• We need to consider residents' attention spans n=2 • Program should be more repetitive with less time per session n=2 • We should build up to longer sessions n=1

	• 1.5-2 hours okay for some, not all n=1 • 1-1.5 hours is appropriate n=2 (n=1 said sessions should be 1 hour only) • In general, program takes too much time n=1	• Residents will have varying abilities n=1
<u>Session Frequency</u> 2 sessions/week	• Good n=13 (n=1 said this frequency would be good *if* they end up liking the program) • Could have >2 sessions/week (usually suggested 3 sessions/week) n=4 • In general, program takes too much time n=1 • Residents may choose to only attend 1 session/week n=1	• We could hold one session on the weekend n=1 • Will take time to get the program going and get people involved n=1 • Will need to alternate days with yoga classes n=1
Other activities they would suggest adding	• Nothing they would want to add to the program n=5 • Game-like/enjoyable activities n=4 • Would like their facility to add exercise machines n=2 • Functional activities n=1 • Mental/hand-eye coordination n=1 • Training in proper techniques n=1 • Stairs n=1 • Swimming n=1 • Yoga n=1 • Liked that current program in their facility includes a massage after working upper extremity muscles n=1	

How interested would you be in participating?	• Interested n=13 • Would give it a try n=5 -thinks it might be designed for those with decreased abilities n=1 -depends on time of year (less likely in winter to walk over) n=1 -depends on health n=1 -depends on motivation n=1 -depends on ability to do the program (with poor balance) n=1 • Not interested in PA n=1 • Don't need n=1	• Factors mentioned influencing participation -Health n=2 -Wanting to help the program n=1 -Whether they like it n=1 -Seeing progress n=1 -Commitment level n=1 -Time of day (not morning) n=1 • It will be helpful to learn to do exercises on their own n=1
How interested would other residents be?	• Interest will vary (some will, some won't) n=8 • It will be a challenge to recruit n=3 • Not many will be interested n=2 • Will really like it if… -it is enjoyable n=1 -they can see benefits n=1 • We will need something catchy, incentives n=2 • Unsure n=2 • Residents may join later (after they have seen others participate) n=1	• Residents may not be interested in PA n=3 • Some residents may not have focus or ability to participate n=3 • The program would be helpful for residents n=2 • Some may not stick with it n=2 • The program is more than they typically do on their own n=1

Session Time of Day	• Morning n=10 -mornings less busy n=5 -morning person n=1 -more alert n=2 -people fall apart in the afternoon n=1 -get it done right away n=1 -people nap in the afternoon n=1 • Either morning or afternoon n=5 • Afternoon n=4 -don't always get up in time n=1 -more time in afternoon n=1 -wouldn't participate in am n=1	• Will need to schedule around other activities at the facility n=6
Equipment Preferences (Hand weights vs. exercise bands)	• Either/try both n=8 • Weights n=5 • Not sure/no experience with one or other n=2 • Exercise bands n=1 • May depend on individual abilities n=1	• Consider if weights are safe n=1 • Consider ease of transporting equipment (weights might be more difficult) n=1
How long are you able to stand?	• <30 minutes (several said 10 minutes) n=8 • Not limited n=6 • Not sure, never stands still n=3 • 45-60 minutes n=2	• Standing can cause pain or dizziness n=3 • Depends on how they're feeling n=1 • Can stand longer with assistive device n=1

How far are you able to walk?	• Not too limited n=10 • Limited n=9 -across parking lot to other building -affected by foot pain -only walks to meals -difficulty walking uphill -10 minutes -1-2 blocks, then hip, knee problems -gets out of breath -1/2 mile with walker and stopping to rest -limited by hip arthritis	• Can walk longer with assistive device n=2 • It is easier when there is less traffic in the hallways n=1
Wearing Garmin (wrist-worn pedometer)[a] In some interviews, the participants were shown the device to see how well they could read the screen	• Yes, would be willing to wear n=11 • Able to read screen n=8 -but might be too small for others n=2 • Difficult to read screen n=1	• Could be used as incentive n=1 • There is a risk of residents losing the device n=1
Study Measures[a]	• Willing to complete n=13	• Those who have completed can speak to how easy it is n=1 • Will be interested in seeing study outcomes n=1

<u>Framing Program Goal</u> Increasing light physical activity vs. decreasing sedentary time	• Increase activity n=12 -positive n=5 -promote something vs. telling not to do something n=1 -telling to decrease sitting sounds like accusing of laziness n=1 -lift into something better n=1 -easier to track n=1 -they won't like a decrease sitting message n=1 • Decrease sitting n=5 -more motivating because less opportunities to be active in small apartment n=1 -recognizes sitting problem n=3 -people may not realize how long they sit n=1 • Both (could frame it both ways) n=2 • Not interested n=1	• Frame it as starting small and building to the goal (don't have to start with 30 min.) n=1
General suggestions	• Residents will have a range of abilities n=5 • Some will be limited n=4 • Should we stretch before walking? n=4 • Recruitment may be challenging (unsure if people will join) n=3 • Important for residents to know their limits n=2 • Kudos to us for planning the program n=2 • We should address their interest in maintaining PA and abilities (many become discouraged with aging) n=1 • Need to define our target population n=1 • Need to find the right activities to include in the program n=1 • Include music n=1 • Need to get with the people (see if they like it, get them onboard) n=1	

	• They need to see the benefits and see how others like the program (might take some time) n=1 • Opportunity to work on thing can't do on own (balance) n=1 • Program is necessary n=1 • Safety, monitoring is important n=1 • Two groups may be needed for residents of different abilities n=1 • Consider planning an intervention for those who are more active and able (could be in conjunction with staff interested in exercise) n=1

[a]Question on this topic was added later to the interview guide and was not posed to all participants.
Note: The "Main Responses" column contains mutually exclusive categories and each resident is only represented by one response in that column. "Other responses" are responses that residents gave in addition to their main response and residents could be represented in more than one category.

Table 4.2. Themes and sub-themes from the thematic analysis.

Attitudes and Beliefs about Physical Activity
Significance of Physical Activity
Motivation and Confidence for Physical Activity
Safety Concerns
Attitudes and Beliefs about Aging
Perspectives on Aging
Appropriate Level of Physical Activity in Older Age
Abilities of Assisted Living Residents
Physical and Mental Limitations
Wide Range of Abilities
Social Influences for Physical Activity
Encouragement to be Physically Active
Group Exercise Preference
Space for Being Active
Current Exercise Classes Offered
Limited Opportunities for Physical Activity

References

ATLAS.ti. (2018). *ATLAS.ti Statistical Software*. In ATLAS.ti Scientific Software Development GmbH.

Bender, A. A., Halpin, S. N., Kemp, C. L., & Perkins, M. M. (2021). Barriers and Facilitators to Exercise Participation Among Frail Older African American Assisted Living Residents. *J Appl Gerontol*, *40*(3), 268-277.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2).

Chen, Y.-M., Li, Y.-P., & Yen, M.-L. (2015). Gender differences in the predictors of physical activity among assisted living residents. *Journal of Nursing Scholarship*, *47*(3), 211-218. https://doi.org/10.1111/jnu.12132

Del Pozo Cruz, B., Biddle, S. J. H., Gardiner, P. A., & Ding, D. (2021). Light-Intensity Physical Activity and Life Expectancy: National Health and Nutrition Survey. *Am J Prev Med*, *61*(3), 428-433. https://doi.org/10.1016/j.amepre.2021.02.012

Dillon, K., & Prapavessis, H. (2020). REducing SEDENTary Behavior Among Mild to Moderate Cognitively Impaired Assisted Living Residents: A Pilot Randomized Controlled Trial (RESEDENT Study). *J Aging Phys Act*, *29*(1), 27-35. https://doi.org/10.1123/japa.2019-0440

Dionigi, R. A. (2015). Stereotypes of aging: Their effects on the health of older adults *Journal of Geriatrics*, Article 954027. https://doi.org/10.1155/2015/954027

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *J Adv Nurs*, *62*(1), 107-115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Erlenbach, E., McAuley, E., & Gothe, N. P. (2021). The Association Between Light Physical Activity and Cognition Among Adults: A Scoping Review. *J Gerontol A Biol Sci Med Sci*, *76*(4), 716-724. https://doi.org/10.1093/gerona/glab013

Fanning, J., Porter, G., Awick, E. A., WÃ³jcicki, T. R., Gothe, N. P., Roberts, S. A., Ehlers, D. K., Motl, R. W., & McAuley, E. (2016). Effects of a DVD-delivered exercise program on patterns of sedentary behavior in older adults: A randomized controlled trial. *Preventive Medicine Reports*, *3*, 238-243. https://doi.org/10.1016/j.pmedr.2016.03.005

Fanning, J., Rejeski, W. J., Chen, S. H., Guralnik, J., Pahor, M., & Miller, M. E. (2020). Relationships Between Profiles of Physical Activity and Major Mobility Disability in the LIFE Study. *J Am Geriatr Soc*, *68*(7), 1476-1483. https://doi.org/10.1111/jgs.16386

Fernandez, M. E., Ruiter, R. A. C., Markham, C. M., & Kok, G. (2019). Intervention Mapping: Theory- and Evidence-Based Health Promotion Program Planning: Perspective and Examples. *Front Public Health*, *7*, 209.

Giuliani, C. A., Gruber-Baldini, A. L., Park, N. S., Schrodt, L. A., Rokoske, F., Sloane, P. D., & Zimmerman, S. (2008). Physical performance characteristics of assisted living residents and risk for adverse health outcomes. *Gerontologist*, *48*(2), 203-212. https://doi.org/10.1093/geront/48.2.203

Grgic, J., Dumuid, D., Bengoechea, E. G., Shrestha, N., Bauman, A., Olds, T., & Pedisic, Z. (2018). Health outcomes associated with reallocations of time between sleep, sedentary behaviour, and physical activity: a systematic scoping review of isotemporal substitution studies. *Int J Behav Nutr Phys Act*, *15*(1), 69.

Groll, D. L., To, T., Bombardier, C., & Wright, J. G. (2005). The development of a comorbidity index with physical function as the outcome. *Journal of clinical epidemiology*, *58*(6), 595-602. https://doi.org/S0895-4356(05)00021-1 [pii]

Kabboord, A. D., van Eijk, M., van Dingenen, L., Wouters, M., Koet, M., van Balen, R., & Achterberg, W. P. (2019). Reliability and usability of a weighted version of the Functional Comorbidity Index. *Clin Interv Aging*, *14*, 289-299. https://doi.org/10.2147/cia.S185112

Kotlarczyk, M. P., Hergenroeder, A. L., Gibbs, B. B., Cameron, F. A., Hamm, M. E., & Brach, J. S. (2020). Personal and Environmental Contributors to Sedentary Behavior of Older Adults in Independent and Assisted Living Facilities. *Int J Environ Res Public Health*, *17*(17).

Larson, J. L., Covey, M. K., Kapella, M. C., Alex, C. G., & McAuley, E. (2014). Self-efficacy enhancing intervention increases light physical activity in people with chronic obstructive pulmonary disease. *International journal of chronic obstructive pulmonary disease*, *9*, 1081-1090. https://doi.org/10.2147/COPD.S66846 [doi]

Larson, J. L., & Webster, K. E. (2020). Feasibility and acceptability of active for life with COPD, an intervention to increase light physical activity in people with COPD. *Heart & Lung*, *49*(2), 132-138. https://doi.org/10.1016/j.hrtlng.2020.01.002

Manas, A., Del Pozo-Cruz, B., Garcia-Garcia, F. J., Guadalupe-Grau, A., & Ara, I. (2017). Role of objectively measured sedentary behaviour in physical performance, frailty and mortality among older adults: A short systematic review. *European Journal of Sport Science*, *17*(7), 940-953. https://doi.org/10.1080/17461391.2017.1327983 [doi]

Manãs, A., Del Pozo-Cruz, B., Rodríguez-Gómez, I., Leal-Martín, J., Losa-Reyna, J., Rodríguez-Manãs, L., Garciá-Garciá, F. J., & Ara, I. (2019). Dose-response association between physical activity and sedentary time categories on ageing biomarkers [Article]. *BMC geriatrics*, *19*(1), Article 270. https://doi.org/10.1186/s12877-019-1284-y

McAuley, E., Wójcicki, T. R., Gothe, N. P., Mailey, E. L., Szabo, A. N., Fanning, J., Olson, E. A., Phillips, S. M., Motl, R. W., & Mullen, S. P. (2013). Effects of a DVD-delivered exercise intervention on physical function in older adults. *J Gerontol A Biol Sci Med Sci*, *68*(9), 1076-1082. https://doi.org/10.1093/gerona/glt014

Mihalko, S. L., & Wickley, K. L. (2003). Active living for assisted living: Promoting partnerships within a systems framework. *American Journal of Preventive Medicine*, *25*(3 Suppl 2), 193-203. https://doi.org/S0749379703001843 [pii]

Milian, M., Leiherr, A. M., Straten, G., Müller, S., Leyhe, T., & Eschweiler, G. W. (2012). The Mini-Cog versus the Mini-Mental State Examination and the Clock Drawing Test in daily clinical practice: screening value in a German Memory Clinic. *Int Psychogeriatr*, *24*(5), 766-774. https://doi.org/10.1017/s1041610211002286

Morgan, L. A., Rubinstein, R. L., Frankowski, A. C., Perez, R., Roth, E. G., Peeples, A. D., Nemec, M., Eckert, J. K., & Goldman, S. (2014). The facade of stability in assisted living. *J Gerontol B Psychol Sci Soc Sci*, *69*(3), 431-441.

Naber, A., Lucas Molitor, W., Farriell, A., Honius, K., & Poppe, B. (2020). The Exploration of Occupational Therapy Interventions to Address Sedentary Behavior and Pain Among Older Adults [Journal Article]. *Journal of Aging and Physical Activity*, *28*(3), 391-398. http://proxy.lib.umich.edu/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=gnh&AN=EP143368926&site=ehost-live&scope=site

Park, S., Thogersen-Ntoumani, C., Ntoumanis, N., Stenling, A., Fenton, S. A., & Veldhuijzen van Zanten, J. J. (2017). Profiles of Physical Function, Physical Activity, and Sedentary Behavior and their Associations with Mental Health in Residents of Assisted Living Facilities. *Applied psychology.Health and well-being*, *9*(1), 60-80. https://doi.org/10.1111/aphw.12085 [doi]

Phillips, L. J., & Flesner, M. (2013). Perspectives and experiences related to physical activity of elders in long-term-care settings. *J Aging Phys Act*, *21*(1), 33-50. https://doi.org/10.1123/japa.21.1.33

Resnick, B., Galik, E., Gruber-Baldini, A., & Zimmerman, S. (2011). Testing the effect of function-focused care in assisted living. *Journal of the American Geriatrics Society*, *59*(12), 2233-2240. https://doi.org/10.1111/j.1532-5415.2011.03699.x [doi]

Rojer, A. G. M., Ramsey, K. A., Amaral Gomes, E. S., D'Andrea, L., Chen, C., Szoeke, C., Meskers, C. G. M., Reijnierse, E. M., & Maier, A. B. (2021). Objectively assessed physical activity and sedentary behavior and global cognitive function in older adults: a systematic review. *Mech Ageing Dev*, *198*, 111524. https://doi.org/10.1016/j.mad.2021.111524

Taylor, W. C., Rix, K., Gibson, A., & Paxton, R. (2020). Sedentary behavior and health outcomes in older adults: A systematic review. *AIMS Medical Science*, *7*(1), 10-39. https://doi.org/10.3934/medsci.2020002

Vos, C. (2017). Physical Activity in Assisted Living Facility Residents.

Vos, C. M., Saint Arnault, D. M., Struble, L. M., Gallagher, N. A., & Larson, J. L. (2019). The Experience and Meaning of Physical Activity in Assisted Living Facility Residents. *J Aging Phys Act*, *27*(3), 406-412. https://doi.org/10.1123/japa.2018-0026

Voss, M. L., Pope, J. P., & Copeland, J. L. (2020). Reducing Sedentary Time among Older Adults in Assisted Living: Perceptions, Barriers, and Motivators. . *International Journal of Environmental Research and Public Health*, *17*.

Voss, M. L., Pope, J. P., Larouche, R., & Copeland, J. L. (2020). Stand When You Can: Development and pilot testing of an intervention to reduce sedentary time in assisted living [Article]. *BMC geriatrics*, *20*(1), Article 277. https://doi.org/10.1186/s12877-020-01647-z

Chapter V

Summary

High levels of sedentary behavior are common in older adults and contribute to a number of adverse health outcomes, including frailty, declines in physical and cognitive function, and mortality (Jefferis et al., 2018; Manas, Del Pozo-Cruz, Garcia-Garcia, Guadalupe-Grau, & Ara, 2017; Mañas et al., 2019; Rojer et al., 2021). There were gaps in the literature related to volume of sedentary behavior in the oldest old, optimal sedentary behavior measurement methods in adults with chronic illness, and interventions to address sedentary behavior in older adults in assisted living. This dissertation sought to address these gaps.

The systematic review and meta-analysis (Paper 1) aimed to characterize sedentary behavior in community-dwelling adults age 80 and older, including their volume of device-measured sedentary behavior and factors influencing their sedentary behavior. We searched four electronic databases and identified 21 articles that met inclusion criteria. Studies utilized a variety of devices and measurement methods, but the meta-analysis of results with hip-worn ActiGraph and the common cut-point of <100 vertical axis counts per minute found that oldest old adults are sedentary for 10.6 hours per day. Few studies explored influencing factors on sedentary behavior in this age group. Factors associated with increased sedentary time included older age, male gender, non-Hispanic white race/ethnicity, social disadvantage, and declining cognitive function (in men).

Paper 2 reported on a measurement study that aimed to identify optimal methods for processing device-measured sedentary behavior data in adults age ≥50 with chronic obstructive pulmonary disease. This secondary analysis included data from 59 participants who had worn ActiGraph and activPAL devices concurrently for seven days. ActiGraph data were processed using a variety of techniques, including 30 combinations of different types of data (vertical axis, vector magnitude), filters (normal, low frequency extension), non-wear algorithm lengths (60, 90, 120 minutes), and cut-points for sedentary behavior previously validated in older adults. Sedentary times derived using the 30 ActiGraph techniques were compared to activPAL-measured sedentary time using Bland-Altman analysis. The technique that showed the closest agreement with activPAL sedentary time utilized vector magnitude data with low frequency extension filter, 120-minutes non-wear algorithm, and a sedentary behavior cut-point of <40 counts per 15 seconds (concordance correlation 0.838; mean difference -11.7 minutes/day). However, several techniques performed similarly, indicating that various techniques may be acceptable if paired with appropriate cut-points.

The final project (Paper 3) was a qualitative study that aimed to gather feedback from assisted living residents on a proposed Active for Life in Assisted Living intervention and explore contextual factors that may influence how the intervention will be implemented with this population. We interviewed 20 older adults residing in four assisted living facilities and analyzed interview data using content and thematic analysis. In the content analysis we found that residents overall like the planned intervention activities (walking, behavioral activities, and circuit training). They suggested shorter intervention sessions, a shorter intervention length, and framing the goal of the intervention in terms of increasing light physical activity rather than reducing sedentary behavior. In the thematic analysis we identified 7 themes and 9 sub-themes related to factors that may influence intervention implementation. The main themes were attitudes and beliefs about physical activity, attitudes and beliefs about aging, abilities of assisted living residents, social influences for physical activity, space for being active, current exercise classes offered, and limited opportunities for physical activity.

A limitation of the systematic review was that we only included articles published in English. Gaps in the literature limited the findings of the review. Most studies used inappropriate cut-points with accelerometers and only a small number of studies used the highly-valid activPAL device. We did not find any studies that identified modifiable factors influencing sedentary behavior in this age group. Limitations of the measurement study were a modest sample size and results that may not be generalizable to other populations. For the qualitative study, it is unknown how the results would generalize to residents in various assisted living facilities. We may have recruited more active residents with higher levels of physical function compared to the general population of older adults in assisted living. Finally, there are likely additional factors influencing intervention implementation that were not identified in our secondary analysis.

Future studies in oldest old adults should explore factors influencing sedentary behavior using longitudinal study designs and measure sedentary behavior with optimal methods, especially validated devices such as activPAL that utilize postural information. ActiGraph techniques for measuring sedentary behavior should be validated in additional older adult populations, including assisted living residents. Building on the qualitative study, future studies should test the feasibility and acceptability of the modified Active for Life in Assisted Living intervention.

The findings of this dissertation have clinical practice implications. There is opportunity to counsel older adults on their potential for reducing sedentary time by emphasizing increases in light physical activity. Nurses can provide education on the harmful effects of sedentary behavior and support older adults to safely participate in physical activity. With further refinement and testing, the Active for Life in Assisted Living intervention could have important implications for helping older adults in assisted living avoid or delay the need for higher levels of care and maintain their health, independence, and quality of life.

In conclusion, this dissertation found that adults age ≥80 are highly sedentary and there is a paucity of evidence on factors influencing their sedentary behavior. We identified optimal methods for measuring sedentary time in adults age ≥50 with chronic obstructive pulmonary disease and found that the ActiGraph device can be used as to accurately measure sedentary time if appropriate techniques are chosen. The results can guide ActiGraph data processing decisions in future work. In addition, we gathered suggestions from older adults in assisted living for modifying the proposed Active for Life in Assisted Living intervention. A number of factors were identified that should be considered in planning a sedentary behavior intervention in this setting. The qualitative study was an important step in developing an intervention that will appropriately address the needs of the assisted living population.

References

Jefferis, B. J., Parsons, T. J., Sartini, C., Ash, S., Lennon, L. T., Papacosta, O., . . . Whincup, P. H. (2018). Objectively measured physical activity, sedentary behaviour and all-cause mortality in older men: Does volume of activity matter more than pattern of accumulation? *British journal of sports medicine*. doi:10.1136/bjsports-2017-098733

Manas, A., Del Pozo-Cruz, B., Garcia-Garcia, F. J., Guadalupe-Grau, A., & Ara, I. (2017). Role of objectively measured sedentary behaviour in physical performance, frailty and mortality among older adults: A short systematic review. *European Journal of Sport Science, 17*(7), 940-953. doi:10.1080/17461391.2017.1327983 [doi]

Mañas, A., Del Pozo-Cruz, B., Rodríguez-Gómez, I., Leal-Martín, J., Losa-Reyna, J., Rodríguez-Mañas, L., . . . Ara, I. (2019). Dose-response association between physical activity and sedentary time categories on ageing biomarkers. *BMC Geriatr, 19*(1), 270. doi:10.1186/s12877-019-1284-y

Rojer, A. G. M., Ramsey, K. A., Amaral Gomes, E. S., D'Andrea, L., Chen, C., Szoeke, C., . . . Maier, A. B. (2021). Objectively assessed physical activity and sedentary behavior and global cognitive function in older adults: a systematic review. *Mech Ageing Dev, 198*, 111524. doi:10.1016/j.mad.2021.111524

APPENDICES

Appendix A

Paper 1 Appendix

Table A.1. Objective measures of sedentary behavior: devices and data processing

Article Author (Year Published)	Device Used	Cut-Point or Determination of SB	Non-Wear Algorithm[a]	Device Wear Period	Minimum Wear Requirements to be Included in Analysis	Mean Wear Time[b]
Arnardottir et al. (2012)	ActiGraph GT3X	<100 cpm	-	Waking hours for 7 days	4 days with 10 hrs of wear time	Women 80-84 yrs: 13.4 hrs/day Women ≥85 yrs: 12.9 hrs/day Men 80-84 yrs: 13.6 hrs/day Men ≥85 yrs: 13.6 hrs/day
Berkemeyer et al. (2016)[c]	ActiGraph GT1M	<100 cpm	90 min.	Waking hours for 7 days	4 days with 10 hrs of wear time	14.5 hrs/day (all subjects 49-91 years)
Chastin et al. (2014)	ActiGraph AM-7164	<100 cpm	60 min.	Waking hours for 7 days	5 days with 10 hrs of wear time (at least 1 weekend day)	-
Chen et al. (2015)	Active Style Pro HJA-350IT	≤1.5 METS	60 min.	Waking hours for 7 days	4 days with 10 hrs of wear time	13.8 hrs/day (all subjects ≥65 years)

Article Author (Year Published)	Device Used	Cut-Point or Determination of SB	Non-Wear Algorithm[a]	Device Wear Period	Minimum Wear Requirements to be Included in Analysis	Mean Wear Time[b]
Cukic et al. (2018)	activPAL3c	Thigh position	-	24 hours for 7 days[d]	7 full days	-
Davis et al. (2011)	ActiGraph GT1M	<100 cpm	100 min.	Waking hours for 7 days	5 days with 10 hrs of wear time	80-84 yrs: 13.9 hrs/day ≥85 yrs: 14.1 hrs/day
Dunlop et al. (2015)	ActiGraph AM-7164	<100 cpm	60 min.	Waking hours for 7 days	4 days with 10 hrs of wear time	13.8 hrs/day[e]
Evenson et al. (2012)	ActiGraph AM-7164	<100 cpm	60 min.	Waking hours for 7 days	3 compliant days	-
Evenson et al. (2014)	NYC sample: ActiGraph GT1M and GT3X NHANES sample: AM-7164	<100 cpm	60 min.	Waking hours for 7 days	4 days with 10 hrs of wear time	NYC sample: 13.6 hrs/day (all subjects ≥60 yrs) NHANES sample:14.1 hrs/day (all subjects ≥60 yrs)
Hooker et al. (2016)	Actical	<50 cpm	150 min.	Waking hours for 7 days	4 days with 10 hrs of wear time	14.9 hrs/day[e]
Jefferis et al. (2015)	ActiGraph GT3X	<100 cpm	90 min.	Waking hours for 7 days	3 days with 10 hrs of wear time	14.1 hrs/day[e]
Lohn-Seiler et al. (2014)	ActiGraph GT1M	<100 cpm	60 min.	Waking hours for 7 days	4 days with 10 hrs of wear time	14.0 hrs/day (all subjects 65-85 years)
Okely et al. (2019)	activPAL3c	Thigh position	-	24 hours for 7 days[d]	7 full days	-

Article Author (Year Published)	Device Used	Cut-Point or Determination of SB	Non-Wear Algorithm[a]	Device Wear Period	Minimum Wear Requirements to be Included in Analysis	Mean Wear Time[b]
Rosenberg et al. (2020)	ActiGraph wGT3X+ ActivPAL micro	≤18 vector magnitude counts/15 seconds Thigh position	90 min. (ActiGraph)	24 hours for 7 days[d]	4 days with 10 hrs of wear time	Not given, but analyses adjusted for wear time
Ryan et al. (2019)	GENEActiv Original	Seated/reclined position with <0.057 Residual G (<1.5 METs)	-	24 hours for 7 days	6 days of 24 hr data	-
Sagelv et al. (2019)	ActiGraph wGT3X-BT	Vertical <100 cpm Vector Magnitude <150 cpm	20 min.	24 hours for 8 days	4 days with 10 hrs of wear time	≥80 yrs: 16.2 hrs/day
Santos et al. (2018)	ActiGraph GT1M	<100 cpm	60 min.	Waking hours for 4 days	3 days with 10 hrs of wear time (including 1 weekend day)	Women 80-84 yrs: 13.6 hrs/day women ≥85 yrs: 13.5 hrs/day Men 80-84 yrs: 13.3 hrs/day Men ≥85 yrs: 13.2 hrs/day
Shaw, Cukic, Deary, Gale, Chastin, Dall,	activPAL3c	Thigh position	-	24 hours for 7 days[d]	7 full days	-

Article Author (Year Published)	Device Used	Cut-Point or Determination of SB	Non-Wear Algorithm[a]	Device Wear Period	Minimum Wear Requirements to be Included in Analysis	Mean Wear Time[b]
Dontje et al. (2017)						
Shaw, Cukic, Deary, Gale, Chastin, Dall, Skelton et al. (2017)	activPAL3c	Thigh position	-	24 hours for 7 days[d]	7 full days	-
Suzuki et al. (2020)	ActiGraph GT3X	<100 cpm	60 min.	24 hours for 7 days	4 days with 10 hrs of wear time	Men: 18.5 hrs/day Women: 18.4 hrs/day
Yonemoto et al. (2019)	Style pro HJA 350-IT	≤1.5 METs	60 min.	Waking hours for 7 days	4 days with 10 hrs of wear time	≥80 measured in 2009: 13.0 hrs/day ≥80 measured in 2012: 13.2 hrs/day

Note: A hyphen indicates non-wear algorithm was not used/not reported or that mean wear time was not reported.

[a] Non-wear algorithm is the minimum length of little or no activity required for a period of time to be considered non-wear time (device was likely removed).

[b] Mean wear times reported apply to the same age group as the sedentary time results in Table 2.1 in the main text unless otherwise specified (wear time specific to the age category included in this review was not always reported).

[c] We only report on the EPIC-Norfolk dataset from this article. NHANES data is included in the article also, but is only reported graphically.

[d] Subjects kept a sleep diary that was used to isolate sedentary behavior during waking hours.

[e] Wear time not explicitly reported, but was calculated based on reported sedentary hrs/day and % of wear time in sedentary behavior.

Appendix B

Paper 2 Appendix

Table B.1. All ActiGraph data processing combinations

Type of Data	Filter	Non-Wear Algorithm Length	Cut-point	Cut-point References
Vertical	Normal	60	<1 count/15s	Evenson (Evenson et al., 2015); Koster (Koster et al., 2016)
Vertical	Normal	60	<10 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
Vertical	Normal	90	<1 count/15s	Evenson (Evenson et al., 2015); Koster (Koster et al., 2016)
Vertical	Normal	90	<10 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
Vertical	Normal	120	<1 count/15s	Evenson (Evenson et al., 2015); Koster (Koster et al., 2016)
Vertical	Normal	120	<10 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
Vertical	LFE	60	<1 count/15s	Evenson (Evenson et al., 2015); Koster (Koster et al., 2016)
Vertical	LFE	60	<10 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
Vertical	LFE	90	<1 count/15s	Evenson (Evenson et al., 2015); Koster (Koster et al., 2016)
Vertical	LFE	90	<10 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
Vertical	LFE	120	<1 count/15s	Evenson (Evenson et al., 2015); Koster (Koster et al., 2016)
Vertical	LFE	120	<10 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
VM	Normal	60	<19 counts/15s	Evenson (Evenson et al., 2015)
VM	Normal	60	<20 counts/15s	Koster (Koster et al., 2016)

Type of Data	Filter	Non-Wear Algorithm Length	Cut-point	Cut-point References
VM	Normal	60	<70 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
VM	Normal	90	<19 counts/15s	Evenson (Evenson et al., 2015)
VM	Normal	90	<20 counts/15s	Koster (Koster et al., 2016)
VM	Normal	90	<70 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
VM	Normal	120	<19 counts/15s	Evenson (Evenson et al., 2015)
VM	Normal	120	<20 counts/15s	Koster (Koster et al., 2016)
VM	Normal	120	<70 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
VM	LFE	60	<20 counts/15s	Koster (Koster et al., 2016)
VM	LFE	60	<40 counts/15s	Evenson (Evenson et al., 2015)
VM	LFE	60	<70 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
VM	LFE	90	<20 counts/15s	Koster (Koster et al., 2016)
VM	LFE	90	<40 counts/15s	Evenson (Evenson et al., 2015)
VM	LFE	90	<70 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)
VM	LFE	120	<20 counts/15s	Koster (Koster et al., 2016)
VM	LFE	120	<40 counts/15s	Evenson (Evenson et al., 2015)
VM	LFE	120	<70 counts/15s	Aguilar-Farias (Aguilar-Farias et al., 2014)

Abbreviations: LFE, low frequency extension filter; VM, vector magnitude; s, seconds. Vertical refers to data derived from only the vertical axis.

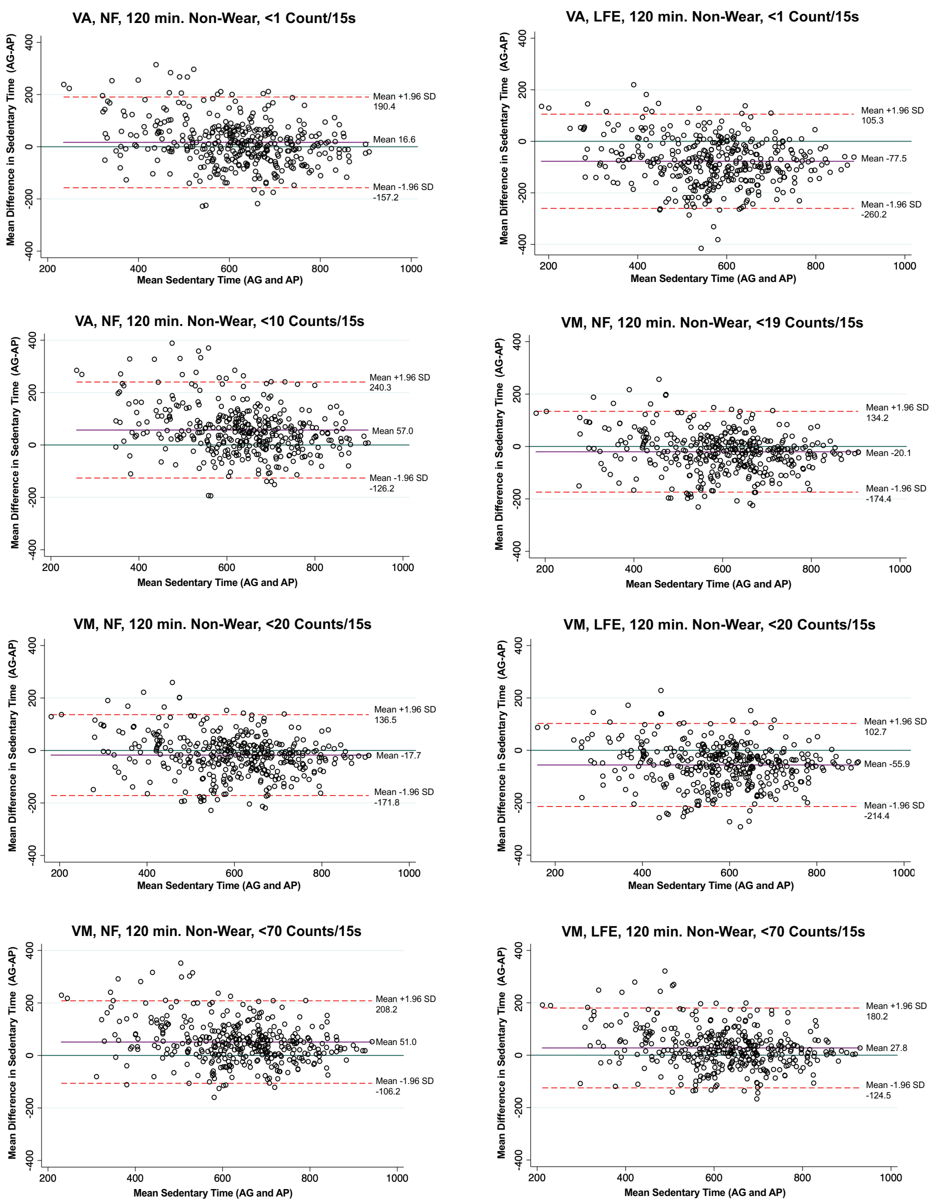

Figure B.1. Bland-Altman Plots comparing sedentary time (waking minutes/day) measured by the ActiGraph and activPAL. These plots represent each combination of number of axes, filter, and cut-point that were not included in Figure 3.1, each with the 120-minute non-wear algorithm.
Y=0 is the line of perfect average agreement. Solid lines represent mean difference. Dashed lines indicate 95% limits of agreement.
Abbreviations: AG, ActiGraph; AP, activPAL; LFE, low frequency extension filter; NF, normal filter; s, seconds; VA, vertical axis data; VM, vector magnitude data

Appendix C

Table C.1. Interview guide for qualitative study with older adults in assisted living (Paper 3)

Research Topic Areas	General instructions and suggested questions	Additional instructions and probes	Interviewer's memo
Introduction of interviewer; thank you for participating Consenting process	I am a graduate student at the University of Michigan, School of Nursing. Thank you for your time today First, I will read the consent form and answer your questions about the research. You may then decide whether you would like to participate.	This interview will take approximately 60-90 minutes to complete. Set up the audiotapes (two digital recorders), explaining that one is a back-up. Make sure the digital recorder is set with microphone toward the participant, but between both of you.	
Timeframe for interview	I am sensitive to your time and energy level. So there will be times when I bring you back to the topic. The purpose of this research is to learn more about your experience with physical activity and sedentary behavior (sitting or lying during the waking day) as someone residing in assisted living. I will also present a proposed program to help individuals such as yourself decrease their sedentary time and become more active. I would like your feedback on this program. Each of your experiences and feelings is very important to my study. The entire interview takes about 60 minutes to complete		
Key issues • Begin to form a relationship	First, please tell me briefly about what it is like to live here. What is a typical day like for you here?		

• Learn about his/her daily life			
Attitude toward physical activity. How does he/she value physical activity?	In general, how do you think about physical activity? What do you consider physical activity? Do you every worry about your physical activity? If yes, tell me about it. If no, tell me why not.	How do you define physical activity? How important is physical activity to you?	
Learn about their physical activity and sedentary behavior and how it may fluctuate	What kinds of physical activities do you do? What kinds of physical activities do other residents do here? Does your physical activity change from day to day? If yes, what influences how it changes from day to day?		
Learn about culture of physical activity within the facility	What types of activity programs do you have here, if any? Any *exercise* programs? Do you participate? • If yes, what do you like about them? What would you like to see changed? • If you don't participate, why not? What type of space is available here for being active? Do staff encourage you to be physically active? If yes, how and what types of activities are encouraged?		

	Do you have any family members who encourage you to be physically active? Do any friends encourage you to be physically active? Are there any other residents who encourage you to be physically active?		
Learn about activities of daily living and any challenges	How much help do you need with your activities of daily living? Such as… -dressing yourself -housekeeping -doing laundry -bathing -using a toilet -shopping -preparing food		
Present the Active for Life: Assisted Living Intervention for feedback	Have you every participated in exercise classes (throughout your life)? I am designing a program to help older adults who live in assisted living become less sedentary and increase their confidence for being active. I don't know yet if it will be offered at this specific facility, but if it may be offered at a similar assisted living facility so I would like to know what you think about it. This will help me design the program. If I plan it correctly, I would like it to be enjoyable and fun. I will describe this program to you and I will ask for feedback about specific parts of the program, as well as general comments. [Give participants information sheet outlining intervention components]	How was that experience? What did you enjoy or not like?	

	Each session would last for about 1.5-2 hours. The session would start with 5-10 minutes of walking. During the walking, participants are encouraged to walk at their own pace and are allowed to take breaks as needed. • How does the walking portion sound to you? The session would include 20-30 minutes of education. The educational portion will include topics such as the health benefits of decreasing sedentary time, the importance of being active at any age, strategies for being more active, goal setting, and overcoming barriers to being active. • What do you think about this educational part of the session? The last portion of the sessions would be 30-45 minutes of circuit training, which involves various exercise stations with exercises focusing on strength and balance. We would end with stretching. These exercises and stretches would be designed to help the muscles involved in performing activities of daily living, such as dressing, bathing, and toileting. Many people lose these abilities as they age, so these exercises may help maintain those abilities. • How does this sound? The program would take place twice a week for 16 weeks.		

	• What do you think about the length of the program (16 weeks)? [last 5 subjects asked about 12 weeks] • What do you think about the number of sessions per week (2)? • What do you think about the length of each session? (1.5-2 hours) [last 5 subjects asked about 1-1.5 hour sessions] Do you have any other general comments or suggestions about the program I described? Are there any other types of activities you would like to be added to the program? How interested would you be in participating in this program if it were offered here? How interested do you think other residents would be in participating in this program? What time of day do you think would be best for this type of program? Would you prefer to use exercise bands or light hand weights during the exercise circuit? How long are you able to stand? How far are you able to walk? [Show Garmin] How do you feel about wearing a device like this to track your steps during the program? Are you able to read the screen easily? Part of the study would include wearing an activity monitor attached to your thigh for 7 days and completing questionnaires before and after the exercise program. Is that something you would be willing to do?		
Learn about whether a focus on increasing light	If I set a goal for people in this program, I could set 2 kinds of goals. I could say increase light		

physical activity or decreasing sedentary behavior will be more meaningful	physical activity by 30 minutes per day OR I could say decrease sitting time by 30 minutes per day. Which would be more motivating or exciting to you?	Why do you say that?	
	Would it be okay if I come back to you if I have any more questions? We're just starting the study and I may think of something else I need to ask you.		