Title
Take a Stand: A Mixed Methods Approach to Evaluate a Pilot Sedentary Behavior Intervention

Author
Takemoto, Michelle Lynn

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Take a Stand: A Mixed Methods Approach to Evaluate a Pilot Sedentary Behavior Intervention

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Public Health (Health Behavior)

by

Michelle L. Takemoto

Committee in Charge:

University of California, San Diego

Professor Jacqueline Kerr, Chair
Professor Loki Natarajan
Professor Camille Nebeker

San Diego State University

Professor Hala Madanat
Professor Jeanne Nichols

2017

The Dissertation of Michelle L. Takemoto is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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Chair

University of California, San Diego

San Diego State University

2017

DEDICATION

This dissertation is dedicated to my daughter, Eliana Elise Takemoto.

My hope is that you always feel empowered to pursue your dreams and know that I will support you along the way. You are my greatest joy.

EPIGRAPH

The champagne tastes the same if you're standing bolt upright

or sunk back into a sofa,

so you might as well be upright, because you look better.

Anouska Hempel, 75 year old British socialite

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ACKNOWLEDGMENTS

First and foremost, I want to thank Dr. Jacqueline Kerr for being my mentor throughout this process. Not only have you inspired me to persevere even when I wanted to give up, but you have served as a role model for me as a fellow working mom. The dedication you show for your work combined with your amazing skills as a mom are truly remarkable and I am so honored to have had the opportunity to learn from you. There was a tipping point for me in this program. A moment when I did not want to continue. I remember sitting in your office and telling you I could not do it. I remember you gave me a big hug, told me to take the day off to think about it, and said you would support me no matter what I decided. From that day on, I have been determined to prove to myself that I am qualified for the title of “Dr.” and earn my right to sit at the table. Thank you for giving me the space to discover that while continuing to support me in case I fell. My committee, Drs. Camille Nebeker, Loki Natarajan, Jeanne Nichols, and Hala Madanat, has been an incredible support and I am grateful to have had the opportunity to work with them during this process. I also want to thank all my colleagues who have been there for me and rooted for me while I pushed towards the finish line. I am thankful to Suni Godbole for always taking the time to work through my statistics questions and helping me see the forest through the trees.

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This work would not have been possible without the help from my amazing family. To my mom and dad, thank you from the bottom of my heart for stepping up as caregivers for Eliana so I could immerse myself in my work without worrying about her well-being. Watching you with her has been one of my greatest joys and I am so incredibly lucky. And thank you for always reminding me that I am more qualified than I give myself credit and to stop doubting my capabilities. To my sister, thank you for always supporting me and giving me a safe space to vent whenever I felt overwhelmed. Thank you to my in-laws for watching Eliana and supporting me during this process. To A'verria, thank you for always talking me off the ledge, being a shoulder to cry on, and for perpetuating my caffeine addiction through multiple refills when I needed it most. I am grateful to my friends who cheered me on and encouraged me along the way. And finally, to my husband, Glenn - thank you for always challenging me. You continue to inspire me to do my best, in every aspect of my life, and for that I am truly grateful. Our competitiveness with each other motivates me to work towards my goals, if only to be able to "one-up" you every once in a while. I love you very much.

Chapter 1 is currently being prepared for submission for the publication of the material. Co-authors include Suneeta Godbole, Drs. Camille Nebeker, Hala Madanat,

Jeanne Nichols, Loki Natarajan, Dori Rosenberg and Jacqueline Kerr. The dissertation author was the primary investigator and author of this material.

Chapter 2 is currently being prepared for submission for the publication of the material. Co-authors include Suneeta Godbole, Drs. Camille Nebeker, Hala Madanat, Jeanne Nichols, Loki Natarajan, Dori Rosenberg and Jacqueline Kerr. The dissertation author was the primary investigator and author of this material.

Chapter 3, in full, has been submitted for the publication of the material. Co-authors include Brittany Lewars, Katie Crist, Drs. Samantha Hurst, Camille Nebeker, Hala Madanat, Jeanne Nichols, Loki Natarajan, Dori Rosenberg and Jacqueline Kerr. The dissertation author was the primary investigator and author of this material.

VITA AND PUBLICATIONS

EDUCATION

San Diego State University & University of California – San Diego | 2012 - 2017
Joint Doctoral Program in Public Health, San Diego, CA
Health Behavior Track

University of California, San Diego | 2003 - 2007
Bachelor of Science in Cognitive with a Specialization in Neuroscience
Bachelor of Arts in Psychology

RESEARCH EXPERIENCE

Graduate Student Research Assistant | March 2015 – present
San Diego State University and University of California, San Diego JDP
Exploring research questions generated from a sedentary behavior pilot intervention including a study of the agreement between self-report and device-based measures of sedentary time, a qualitative analysis on focus group data, and a mixed methods analysis on how tool use impacts sedentary time.

Department of Family Medicine & Public Health | San Diego, CA | September 2012 – present
University of California San Diego
Administrative Study Coordinator
Oversee and manage study reporting, evaluation and coordination tasks for a NHLBI funded R01 project. Organize recruitment and enrollment of participants, train and monitor lay peer leaders, develop process and implementation measures and administer study assessments. Prepare and revise IRB applications, modifications and progress reports for the university and prepare project reports for NHLBI describing all aspects of study progress. Prepare and lead biweekly case management meetings with all program staff. Oversee all adverse events and ensure all event reporting occurs in a timely manner according to study procedures.

PUBLICATIONS

Nebeker, C., Lagare, T., **Takemoto, M.**, Lewars, B., Crist, K., Bloss, C.S., Kerr, J. (2016). Engaging research participants to inform the ethical conduct of mobile imaging, pervasive sensing, and location tracking research. *Translational Behavioral Medicine,* 1-10. [Epub ahead of print]

Meseck, K., Jankowska, M.M., Schipperijn, J., Natarajan, L., Godbole, J., **Takemoto, M**., Crist, K., Kerr, J. (2016). Is missing geographic positioning system data in accelerometer studies a problem and is imputation the solution? *Geospatial Health*, 11(2): 403. doi: 10.4081/gh.2016.403.

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

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Dumbauld J, **Black M**.L., Depp CA, Daly R, Curran MA, Winegarden B and Jeste DV. Association of learning styles with research self-efficacy: Study of short-term research training program for medical students. *Clinical and Translational Science* (submitted 2014).

Black, M.L., Curran, M.C., Golshan, S., Daly, R., Depp, C., Kelly, C., Jeste., D.V. (2013). Summer Research Training for Medical Students: Impact on Research Self-Efficacy. *Clinical and Translational Science*. doi: 10.1111/cts.12062.

Israel, S., Seibert, T., **Black, M.L,** Brewer, J. (2009). Going Their Separate Ways: Dissociation of Hippocampal and Dorsolateral Prefrontal Activation during Episodic Retrieval and Postretrieval Processing. *Journal of Cognitive Neuroscience, 22,* 513-525.

MANUSCRIPTS IN PROGRESS

Rich, P., Aarons, G., Cardenas, V., Crist, K., Bolling, K., Lewars, B., Castro-Sweet, C., Natarajana, L., Shi, Y., Full, K.M., Johnson, E., **Takemoto, M.,** & Kerr, J. Implementation-Effectiveness Trial of an Ecological Intervention for Physical

Activity in Ethnically Diverse Low Income Senior Centers. Contemporary Clinical Trials. Submitted.

Kerr, J., Crist, K., Vital, D., Dillon, L., Aden, S.A., Trivedi, M., Castellanos, L.R., Allison, M., Khemlina, G., **Takemoto, M.,** Schenk, S., Sallis, J., Dunstan, D., Natarajan, L., LaCroix, A.Z., Sears, D.D. Interrupting prolonged sitting time: A pilot laboratory study of glucoregulator and vascular outcomes in postmenopausal women. Submitted.

SCIENTIFIC ORAL PRESENTATIONS

Takemoto, M., Bolling, K., Lewars, B., Crist, K., Johnson, E., Rich, P., Full, K., Kerr, J. *Developing a Sustainable Peer-Led Physical Activity Program for Seniors.* Oral presentation at the Society for Behavioral Medicine Annual Meeting: San Diego, CA, March 29-April 1, 2017.

Black, M.L., Wang, L., Golshan, S., Pena, C., Martin, A., Crist, K., Moran, K., Marshall, S., Kerr, J. (2014). *The relationship between social support and objective physical activity in older adults in Continuing Care Retirement Communities.* Oral presentation at the International Society of Behavioral Nutrition and Physical Activity Annual Meeting: San Diego, CA, May 21-24.

Richey, M., **Black, M.L**, Crist, K., Bolling, K., Lewars, B., Kerr, J. (2014). *Pilot intervention to reduce sitting and increase standing breaks.* Oral presentation at the Epidemiology Research Exchange Annual Conference: San Diego, CA, May 2.

Engelberg, J., **Black, M.L.**, (2014). *Ciclovía Participation and Impacts in San Diego, CA: The First CicloSDias.* Oral presentation at the Active Living Research 2014 Annual Meeting: San Diego, CA, March 9-12.

Rosenberg, D., **Black, M.L.** (2013). *Assuring that Innovative Research Impacts Policy in Residential Long-Term Care.* Oral presentation at the Gerontological Society of America 2013 Annual Meeting: New Orleans, LA, November 19-22.

SCIENTIFIC POSTER PRESENTATIONS

Takemoto, M., Bolling, K., Aarons, G., Rich, P., Johnson, E., Lewars, B., Full, K., Kerr, J. *Developing an Implementation Framework to Evaluate a Community-Based Physical Activity Program for Seniors.* Poster presentation at the Dissemination and Implementation Annual Meeting: Washington, D.C., December 14-15, 2016.

Nebeker, C., Lagare, T., **Takemoto, M.L.**, Lewars, B., Kerr, J., (2015) *Mobile Imagine, Sensing and Tracking Ethics (MIST-E): iWatch Participant Perspectives.* Poster presentation at the Society for Behavioral Medicine Annual Meeting: San Antonio, TX, April 22-25.

Kerr, J., Carlson, J., **Black, M.**L, Merchant, G., Crist, K., Bolling, K., Atkin, A., Marshall, S. (2014) *Feasibility of increasing the length and number of standing breaks in older adults: Results of a pilot study.* Poster presentation at the International Society of Behavioral Nutrition and Physical Activity Annual Meeting: San Diego, CA, May 21-24.

Merchant, G., Carlson, J., Godbole, S., **Black, M.L**, Kerr, J. (2014) *Take a stand: Targeting psychosocial mediators of change to reduce older adults' sedentary behavior.* Poster presentation at the International Society of Behavioral Nutrition and Physical Activity Annual Meeting: San Diego, CA, May 21-24.

Merchant, G., Pina, L., **Black, M.L.**, Bales, E., Weibel, N., Fowler, J., Patrick, K. (2014). *Online and face-to-face: How do ad-hoc and existing networks support weight-related behavior change in young adults?* Poster presented at the Society of Behavioral Medicine 2014 Annual Meeting, Philadelphia, PA, April 23-26.

Black, M.L., Curran, M.A., Depp, C., Iglewicz, A., Reichstadt, J., Palinkas, L., Jeste, D. (2013) *Barriers and Facilitators for Academic Careers in Geriatric Medicine: Medical Students' Perspectives.* Poster presented at the Gerontological Society of America. Annual Meeting, New Orleans, LA, November 19-22.

Israel, S., **Black, M.L.,** Seibert, T., Brewer, J. (2007). *Hippocampal Suppression Following Retrieval of Paired-Associates.* Poster presented at the Society for Neuroscience 2009 Annual Meeting: San Diego, CA, November 3-10.

ADDITIONAL COURSEWORK/TRAINING

CTRI's Life Course Research Workshop| Fall 2016

MED 231 Introduction to Mixed Methods | Spring 2016

FPM 291 Implementation and Dissemination: An Intro | Spring 2015

FPM 296 Intro to Qualitative Methods | Winter 2015

GIS and Active Living Course | Winter 2014

TEACHING ACTIVITIES

Co-Instructor, San Diego State University | Fall Semester 2014

PH661: Theoretical Foundations of Health Promotion (Master's Level Course) in the Graduate School of Public Health

- Responsible for creating and grading student exams and providing feedback on student homework throughout the semester. Independently taught two class lectures

University of California, San Diego

- Invited panelist, JDP Seminar Course, Winter 2014
- Guest lecturer, FPM280A, Health Behavior Practicum, Fall 2014

San Diego State University

- Guest lecturer, PH662, Motivating Health Behavior, Spring 2016
- Teaching Assistant, PH661, Theoretical Foundations of Health Promotion, Fall 2014
- Guest lecturer, PH661, Theoretical Foundations of Health Promotion, Fall 2014
- Guest lecturer, PH700F, Women's Health, Spring 2013

PROFESSIONAL SERVICE

Reviewer, JMIR
Reviewer, Health Psychology
Reviewer, Contemporary Clinical Trials
Reviewer, Transportation and Health
Abstract Reviewer, Dissemination and Implementation Conference
Abstract Reviewer, Gerontological Society of America

FELLOWSHIP AWARDS

University of California, San Diego
Chancellor's Interdisciplinary Collaboratories Fellow, Connected and Open Research Ethics (CORE) Project, University of California, San Diego

ADDITIONAL SKILLS

Proficient in SPSS, ActivPAL, Dedoose
Experienced in IRB compliance

PROFESSIONAL AFFLILIATIONS

Society for Behavioral Medicine
Gerontological Society of America
Seattle Implementation Research Conference Group
Dissemination and Implementation Research Group

ABSTRACT OF THE DISSERTATION

Take a Stand: A Mixed Methods Approach to Evaluate
a Pilot Sedentary Behavior Intervention

by

Michelle L. Takemoto

Doctor of Philosophy in Public Health (Health Behavior)

University of California, San Diego, 2017
San Diego State University, 2017

Professor Jacqueline Kerr, Chair

Background: Society is sitting more than ever before. Large-scale epidemiological evidence indicates that prolonged sitting time has negative health impacts including increased risk of metabolic syndrome, heart disease, weight gain, cancer, and premature mortality. Older adults are an important population to target because they represent the most sedentary segment of the population who struggle to meet activity guidelines. Based on these negative health associations, research on sedentary behavior interventions, especially focused on older adults, is a public health priority.

Methods: This dissertation uses data from a pilot sedentary behavior intervention in 30 adults aged 50-70 years to understand how to measure and prompt sedentary behavior change. The intervention successfully targeted two distinct sitting interruption modalities (i.e., sit less, increase sit-to-stand transitions). Chapter 1 explored differences in self-reported and objectively-measured sitting time to evaluate participants' ability to self-assess behavior during an intervention. Chapter 2 included a mixed methods analysis of tool use to disrupt sitting time during the pilot intervention. Chapter 3 used focus groups to explore participants' perceptions regarding wearable devices to track and change sedentary behavior.

Results: Chapter 1 found significant differences in self-reported sitting time by day of week, employment status, and participation in a sedentary behavior intervention. Chapter 2 showed that participants who used effective tools were most successful in reducing sitting time. In contrast, current tools for increasing sit-to-stand transitions were ineffective. The focus groups from Chapter 3 revealed that participants were amenable to using wearable devices; however, current devices lack key features necessary for sedentary behavior including the ability to accurately measure sitting time and distinguish "inactivity" from standing.

Discussion: Given the negative health outcomes associated with excessive sitting, more interventions are targeting sedentary behavior. The three themes explored in this dissertation (specificity of measurement, tools, and behaviors) and the combination of

analysis methods help increase our understanding of sedentary behavior in older adults. This dissertation provides recommendations to improve the field by using specific measures for sitting time to capture differences across the week, designing interventions to include tools with a specific focus on sedentary behavior, and exploring how technology can help change behavior.

INTRODUCTION

Currently, *eight* babies are born in the United States every minute and *seven* baby boomers turn 65 every minute [1–3]; however, in 2030, only *one* baby will be born every minute, but *seven* baby boomers will continue to turn 65 every minute [1]. These numbers highlight the unprecedented demographic shift that will happen in the next 13 years. With people living longer, a specific focus on how to promote healthy aging has become especially relevant. Increasing physical activity has been a major focus among research for decades based on the numerous benefits associated with being physically active including improved quality of life, decreased risk of cardiovascular disease and metabolic syndrome, and reduced risk of mortality and chronic disease [4–6]. Despite these significant benefits, older adults remain the most inactive segment of the population. When measured objectively via accelerometers, only approximately 3% of older adults are meeting the Centers for Disease Control's guidelines of 150 minutes of moderate-to-vigorous physical activity [7]. Given functional limitations associated with increased age [8], it may not be possible for older adults to reach the required intensity of physical activity to achieve these benefits. Therefore, research into small behavior change strategies that could have health impacts is needed.

A new class of behaviors that has gained attention lately is sedentary behavior, which is defined as a range of human behaviors that result in an energy expenditure of no more than 1.5 times resting energy expenditure and are typically associated with time spent sitting, reclining, or lying down during waking hours [9–11]. The reductions in the demand for physical activity since the middle of the last century have increased the prevalence of sedentary behavior in the population at large [12–14]. Recent epidemiological evidence indicates that on average, adults spend approximately six hours per day sedentary [15] and older adults are sedentary for approximately nine hours per day [16].

The fact that individuals are sitting more is problematic because epidemiological studies have found deleterious effects of prolonged sedentary behavior that are separate from participation in physical activity [17–19]. The negative health outcomes that have since been associated with sedentary behavior include increased risk of weight gain, cancer, metabolic syndrome, diabetes, heart disease, and mortality [11,12,17–19]. A recent report by the American Heart Association highlighted the substantial body of prospective data on the associations of sedentary behavior with increased risk of diabetes mellitus and cardiovascular disease as well as an increased risk of overall mortality [20]. Although some studies have shown that the negative health impacts associated with prolonged sitting are statistically independent of physical activity [17,20], other studies have shown an interaction between these behaviors [21]. Currently, there is some controversy surrounding the role of physical activity in attenuating the negative health outcomes of sedentary behavior in younger populations. Despite this controversy, changing sedentary behavior is an important target for older adults given the functional limitations associated with increasing age that may prevent older adults from engaging in adequate amounts of physical activity needed to attenuate these effects. Based on the negative health associations demonstrated in these prospective and cohort studies [17,20], distinct research is necessary to reduce in sitting time especially targeting the older adult population.

One of the major limitations surrounding sedentary behavior research involves measurement methods. Previous research has measured the amount of sedentary behavior using self-report measures [17,22]. Some questionnaires measure behaviors associated with sedentary behavior (e.g., television time, computer time) as a proxy for calculating overall sedentary time [17]. Other measures rely on participant recall to quantify amounts of sedentary time [17]. This can be extremely challenging due to the unconscious and habitual nature of sedentary behavior which makes it difficult for individuals to quantify absolute values of overall time [23–25]. A number of validation studies have compared self-report to objective measures of sitting time (see **Table i-1**). These studies indicate that although workers may be able to self-assess sitting time with reasonable accuracy across weekdays, the ability to self-assess on other days of the week might not be as precise. Furthermore, older adults who are primarily non-workers may have even more difficulty self-reporting sitting time.

Although objective measures are available, there are also issues that lead to bias in this data including wear time variability (e.g., participants take the device off and forget to put it back on) and data processing techniques. Additionally, cut points used for hip worn accelerometers do not distinguish standing from sitting and instead classify both behaviors under the overall definition of sedentary time [22]. These measurement limitations could mean that current estimates of sedentary behavior may be inaccurate. A new measurement tool called the ActivPAL™ worn on the thigh, has the ability to measure a person's sitting/lying, standing, and stepping behavior [26,27]. Additionally, with proper supplies, the ActivPAL™ can be waterproofed thereby allowing participants to wear the device for 24 hours a day for up to seven days before needing to be taken off to charge. This new tool allows researchers to more adequately capture an individual's entire day and has better classification of posture than other devices.

These advances in methods to objectively measure sedentary behavior have also supported higher quality assessment of intervention studies specifically targeting posture change. Previously, studies focused primarily on increasing physical activity [28,29] with the assumption that an increase in physical activity would result in a decrease in sedentary behavior. However, a recent review of the literature by Prince et al. (2014) discovered that interventions focusing on increasing physical activity have minimal to no impact on sedentary behavior [30]. In contrast, interventions with a clear focus on changing sedentary behavior have resulted in significant reductions in sedentary time (see **Table i-2**). Specifically, physical activity interventions successfully increased minutes per day of physical activity, but only resulted in a mean reduction of 19 minutes per day in sedentary behavior – an amount that is likely insufficient to produce significant health improvements. In contrast, the interventions that focused primarily on sedentary behavior had minimal impact on increasing physical activity, but reduced sitting time by 91 minutes per day – an amount that could potentially result in positive health outcomes. Therefore, future interventions must purposely focus on sedentary behavior alone to successfully change the behavior.

Previous successful sedentary behavior interventions have included an emphasis on theory. In a recent review by Gardner and colleagues [31,32], interventions that had the most impact on behavior change included a strong theoretical foundation and targeted several behavior change constructs (see **Table i-2**). The constructs that showed the most promise included self-monitoring, problem solving, modifying the social and physical environments, and providing education about the negative health impacts of the behavior. Based on the ubiquitous and habitual nature of sedentary behavior, intervening effectively may require even more cues and prompts. Therefore, interventions that target multiple behavior change constructs and include an extra emphasis on prompts and cues could be especially effective.

One potential method for changing sedentary behavior that has yet to be thoroughly explored involves the use of technology targeting the behavior. Because sedentary behavior is a pervasive behavior, pervasive sensing through technology may be an effective strategy to change the behavior. Given the recent surge in wearable technology for activity monitoring (e.g. Fitbits) incorporating a sitting focused device similar to those used for physical activity, but specific to sedentary behavior could have dramatic impact on the behavior. The research on sitting is new, so it is not yet a behavior that has had wide scale public health messaging thus, individuals' awareness of the behavior and their ability to conceptualize time spent being sedentary may be limited. Further, sitting is an ingrained habit that we do all day without realizing. A device designed to specifically measure and target sedentary behavior may be especially helpful to provide frequent cues to disrupt this strong habit. Additional research is needed to fully understand how technology can be used to change sedentary behavior.

Chapter 1 contributes to the field of sedentary behavior by providing an in-depth analysis of the comparison between self-reported sitting time and objectively-measured behavior. The aim of Chapter 1 is to explore differences in self-reported and objectively-measured sitting time by intervention status, measurement period, day of week, and employment status to evaluate participants' ability to self-assess behavior during an intervention. Based on the current gaps in the literature related to measuring sedentary behavior, this chapter provides a significant contribution by exploring these differences in an older adult population consisting of both working and non-working individuals. Additionally, these differences are further evaluated by weekday and weekend day to provide a more thorough analysis of potential relationships between these characteristics and sitting time outcomes.

In addition to more refined measures, additional research is needed to understand how to intervene on sedentary behavior in older adults to promote healthy aging. Chapter 2 includes a mixed methods analysis into tool use related to sedentary behavior for two distinct behaviors that disrupt sitting time (sitting less & increasing sit-to-stand transitions). The aim of Chapter 2 is to quantitatively assess tool use change over time and use qualitative analysis to conduct a more in-depth exploration into this relationship. Given the functional limitations associated with increased age [8], identifying alternative behavior change strategies that may have health impacts without the effort of moderate-to-vigorous physical activity or extended standing is important. A more in-depth analysis of behavior change strategies will inform future interventions. By combining both quantitative and qualitative analysis techniques, Chapter 2 provides invaluable insight into how to use tools effectively to change sedentary behavior.

Technology represents a novel strategy to change sedentary behavior that has yet to be thoroughly evaluated. Chapter 3 uses data from focus groups to explore perceptions regarding technology to track and change sedentary behavior. The aim of Chapter 3 is to discuss barriers and facilitators to using current wearable devices on the market in sedentary behavior interventions. With the recent surge in wearable devices, findings from Chapter 2 will inform the design of devices that could be employed in future interventions using technology to change sedentary behavior. This is the first study to explore how perceptions of technology may or may not impact a participant's decision to use technology to change sedentary behavior.

In summary, the purpose of this dissertation is to contribute to the current sedentary behavior literature through a combination of research methods including quantitative, qualitative, and mixed methods analyses (see Figure i-1). The results from this dissertation will inform future research related to sedentary behavior and generate new ideas for intervention strategies and tools. Because there are only a few pilot interventions that have been conducted in older adult populations to date [33–35], the results are relevant and timely to advance this field in a population in need of feasible and effective health interventions. With the number of older adults expected to grow, it is especially important to continue to work to improve health through novel interventions. By using a combination of methods to approach the data, the results from this dissertation provide an extensive analysis of sedentary behavior in older adults.

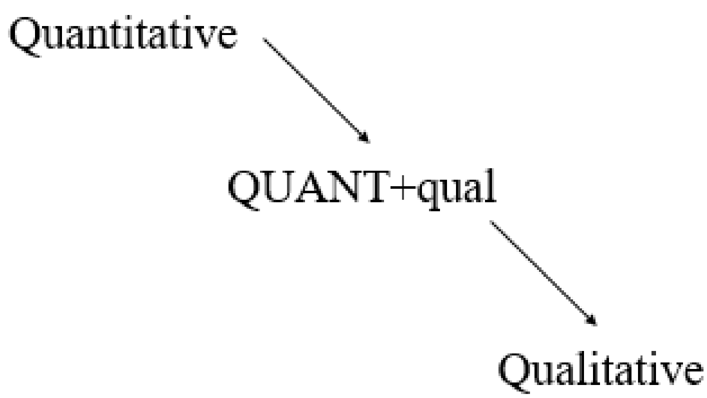

Figure i-1. Conceptual overview of the methods used in the three chapters of the dissertation.

Table i-1. Summary of literature comparing self-reported with objectively-measured sitting time

Author (Year)	**Title**	**Population** Age (y)	**Work status**	**Measurement tool**	**Self-report questionnaire**	**Analyzed by weekend and weekday separately?**	**Direction**
Boyle (2014)	Agreement between accelerometer-assessed and self-reported sedentary time in colon cancer survivors	27-82	N/A	Accelerometer	Marshall	Yes	Under and overestimate
Celis-Morales (2012)	Objective vs. Self-Reported Physical Activity and Sedentary Time: Effects of Measurement Method on Relationships with Risk Biomarkers	18-73	N/A	Accelerometer	IPAQ	No	Underestimate
Chastin (2014)	Comparison of self-reported measure of sitting time (IPAQ) with objective measurement activPAL	18-65	N/A	ActivPAL	IPAQ	No	Underestimate
Chau (2011)	A tool for measuring workers' sitting time by domain: the Workforce Sitting Questionnaire	18 and older	Workers	Accelerometer	IPAQ and Workforce Sitting Questionnaire WSQ)	No	Performed well for measuring workplace sitting
Clark (2013)	Adults' Past-Day Recall of Sedentary Time: Reliability, Validity, and Responsiveness	33-75	Both	ActivPAL and accelerometers	PAST	No	Underestimate
Clark (2016)	Past-day recall of sedentary time: Validity of a self-reported measure of sedentary time in a university population	18-55	Workers	ActivPAL	PAST-U	No	Moderate correlations

Table i-1. Summary of literature comparing self-reported with objectively-measured sitting time (Continued)

Author (Year)	**Title**	**Population** Age (y)	**Work status**	**Measurement tool**	**Self-report questionnaire**	**Analyzed by weekend and weekday separately?**	**Direction**
Cleland (2014)	Validity of the Global Physical Activity Questionnaire (GPAQ) in assessing levels of change in moderate-vigorous physical activity and sedentary behaviour	Adults	N/A	Accelerometer	GPAQ	No	Underestimate
Farias (2014)	Validity of self-report methods for measuring sedentary behavior in older adults	65+	N/A	ActivPAL	MARCA and SQ	Yes	*Single question*- underestimate *24h recall* - overestimate
Gardiner (2011)	Measuring Older Adults' Sedentary Time: Reliability, Validity, and Responsiveness	65+	Non-worker	Accelerometer	SBQ	Yes	Underestimate
Gennuso (2015)	Reliability and Validity of Two Self-report Measures to Assess Sedentary Behavior in Older Adults	65+	N/A	Accelerometer	CHAMPS and YPAS	No	Underestimate
Hekler (2012)	Reliability and Validity of CHAMPS Self-Reported Sedentary-to-Vigorous Intensity Physical Activity in Older Adults	65+	Non-workers	Accelerometer	CHAMPS	No	Underestimate
Jefferis (2016)	Validity of questionnaire-based assessment of sedentary behavior and physical activity in a population-based cohort of older men; comparisons with objectively measured physical activity data	71-93	N/A	Accelerometer	Proxy measures	No	Underestimate

Table i-1. Summary of literature comparing self-reported with objectively-measured sitting time (Continued)

Author (Year)	Title	Population Age (y)	Work status	Measurement tool	Self-report questionnaire	Analyzed by weekend and weekday separately?	Direction
Lagersted-Olsen (2013)	Comparison of Objectively Measured Self-reported Time Spent Sitting	27-59	Workers	Accelerometer	Questions from IPAQ and MOSPAQ	No	Strong correlation for work day hours, but participants generally underestimate leisure sitting time
Marshall (2015)	Patterns of weekday and weekend sedentary behavior among older adults	65+	Mostly non-workers	Accelerometer	SBQ	Yes	Overestimate
Matthews (2013)	Validation of a Previous-Day Recall Measure of Active and Sedentary Behaviors	12-17 and 18-71	Mostly workers	ActivPAL and accelerometer	Previous-day recall	No	Strong correlation
Van Cauwenberg (2014)	Older Adults' reporting of specific sedentary behaviors: validity and reliability	65+	Non-workers	Accelerometer	Adapted IPAQ	No	Underestimate
Van Nassau (2015)	Validity and responsiveness of four measures of occupational sitting and standing	Over 18	Workers	ActivPAL and accelerometer	WSQ and Occupational Sitting and Physical Activity Questionnaire	No	Overestimate
Wijndaele (2014)	Reliability and Validity of a Domain-Specific Last 7-d Sedentary Time Questionnaire	20-60	N/A	ActivPAL or actiheart	SIT-Q-7d	No	Overestimate

Table i-2. Overview of previous sedentary behavior interventions

Author (Year)	Title	Population	Length of study	Goal	Theory or BCTs*	ActivPAL™	Frequency and type of feedback	Tools
Alkhajah (2012)	Sit–Stand Workstations: A Pilot Intervention to Reduce Office Sitting Time	N=32; office workers aged 20-65	3-week intervention 2-month follow-up	Sit less	No	No	In person instructions to use sit-stand workstations	Standing desks
Ashe (2013)	Does an 'Activity-Permissive' Workplace Change Office Workers' Sitting and Activity Time	N=24; office workers	Natural per-post experiment	Reduce sitting and increase physical activity	Environmental changes	Yes	No	Moved to a newly-constructed, purpose-built, movement-oriented workplace
Barone Gibbs (2017)	Reducing Sedentary Behavior Versus Increasing Moderate-to-Vigorous Intensity Physical Activity in Older Adults: A 12-Week Randomized, Clinical Trial	N=38; older adults	12-week intervention	Sit less or Move more	Goal-setting; problem solving; motivational interviewing	No; measured via SenseWear arm band	In-person weekly from Weeks 1 to 4; bi-weekly in-person or phone calls Weeks 5-12	SenseWear arm band that provided real-time via bluetooth
Barwais (2013)	Physical Activity, sedentary behavior and total wellness changes among sedentary adults: a 4-week randomized controlled trial	N=39; adults in Australia	5 week intervention	Reduce sitting and increase physical activity	No	No	N/A	Activity monitor (Gruve Solution™)

Table i-2. Overview of previous sedentary behavior interventions (Continued)

Author (Year)	Title	Population	Length of study	Goal	Theory or BCTs*	ActivPAL™	Frequency and type of feedback	Tools
Buman (2017)	An intervention to reduce sitting and increase light-intensity physical activity at work: Design and rationale of the 'Stand & Move at Work' group randomized trial	N=720; office workers	12-month intervention	Reduce sitting and increase physical activity	Ecological model	Yes	Initial coaching session to set goals with 26 follow-up newsletters sent via email	Standing desks
Chang (2013)	Sedentary behavior, physical activity, and psychological health of Korean older adults with hypertension: effect of an empowerment intervention	N=48; older adults	8 weeks	Healthy lifestyle	Empowerment theory	No	Courses on healthy lifestyle	No
Dewa (2009)	Walking for Wellness: Using Pedometers to Decrease Sedentary Behaviour and Promote Mental Health	N=28; 27-60 years old	4 weeks	Pedometer intervention	No	No	No	Pedometers to track steps
Evans (2012)	Point-of-Choice Prompts to Reduce Sitting Time at Work: A Randomized Trial	N=28; office workers	5 workdays	Sit less	No	No	Educational sessions	Computer program prompts

Table i-2. Overview of previous sedentary behavior interventions (Continued)

Author (Year)	Title	Population	Length of study	Goal	Theory or BCTs*	ActivPAL™	Frequency and type of feedback	Tools
Fitzsimons (2013)	Using an individualised consultation and activPAL feedback to reduce sedentary time in older Scottish adults: Results of a feasibility and pilot study	N=24; Over 60 years of age	2 weeks	Sit less	Ecological model; Michie's BCTs	Yes	One counseling session	No
Gardiner (2011)	Feasibility of reducing older adults sedentary time	N=59; Over 60 years of age	Pre-post design	Sit less	SCT and behavioral choice theory	No; accelerome-ters	Face-to-face goal setting and a tailored mailing	No
Gardner (2014); Matei (2015)	'On Your Feet to Earn Your Seat', a habit-based intervention to reduce sedentary behavior in older adults: study protocol for a randomized controlled trial	N=120; 60-75 years old	8-week uncontrolled trial	Reduce sitting and increase physical activity	Habit formation model	No; self-report	Information leaflets	No
Healy (2013); Dunstan (2013); Neuhaus (2014) Healy (2016)	Reducing sitting time in office workers: Short-term efficacy of a multicomponent intervention	N=43; 26-62 years old	4 weeks	Stand up, sit less, move more	Ecological Model	Yes	1 in-person health coaching session and 1 phone call per week	Standing desks

Table i-2. Overview of previous sedentary behavior interventions (Continued)

Author (Year)	Title	Population	Length of study	Goal	Theory or BCTs*	ActivPAL™	Frequency and type of feedback	Tools
Kerr (2015)	Two-Arm Randomized Pilot Intervention Trial to Decrease Sitting Time and Increase Sit-to Stand Transition in Working and Non-Working Older Adults	N=30; 50-70 years old	2 weeks	Sit less or increase sit-to-stand transitions	SCT	Yes	Weekly in-person counseling	Standing desks; timers; emails; texts; phone calls
King (2016)	Effects of Three Motivationally Targeted Mobile Device Applications on Initial Physical Activity and Sedentary Behavior Change in Midlife and Older Adults: A Randomized Trial	N=95; over 45 years of age	8 weeks	Either sit less or increase physical activity	SCT and self-regulatory principles	No, accelerome-ters	One info session to introduce app	Smartphone app designed specifically for intervention arm
Kozey-Keadle (2011)	The Feasibility of Reducing and Measuring Sedentary Time among Overweight, Non-Exercising OfficeWorkers	N=20; 20-60 years old	One week	Sit less and increase light-intensity activity	SCT	Yes	One information session with intervention staff at first visit	N/A
Maher (2016)	Feasibility and preliminary efficacy of an intervention to reduce older adults' sedentary behavior	N=42; over 60 years old	2 weeks	Sit less	SCT	No	Three 90-minute sessions over two weeks	Informational materials
Mailey (2016)	Comparing the effects of two different break strategies on occupational	N=49 females; office workers	8-week intervention	Short frequent breaks or longer,	No	No, accelerome-ters	Initial meeting with interventionist and phone calls	No

Table i-2. Overview of previous sedentary behavior interventions (Continued)

Author (Year)	Title	Population	Length of study	Goal	Theory or BCTs*	ActivPAL™	Frequency and type of feedback	Tools
	sedentary behavior in a real world setting: A randomized trial			planned breaks				
Mutrie (2016)	Study protocol of European Fans in Training (EuroFIT): a four-country randomized controlled trial of a lifestyle program for men delivered in elite football clubs	N=1,000 males aged 30-65	12-week intervention	Reduce sitting and increase physical activity	Self-Determination Theory and Achievement Goal Theory	Yes	12-weekly, 90-minute sessions	SitFIT (self-monitoring, pocket-worn device)
Pronk (2012)	Reducing Occupational Sitting Time and Improving Worker Health: The Take-a-Stand Project, 2011	N=34; office workers	4 weeks	Sit less	Ecological model	No	N/A	Standing desks
Rosenberg (2015)	The Feasibility of Reducing Sitting Time in Overweight and Obese Older Adults	N=25; older adults	8-weeks	Sit less and increase sit-to-stand transitions	Social Cognitive Theory	Yes	5 phone counseling sessions	No
Verweij (2012)	The application of an occupational health guideline reduces sedentary behavior and increases fruit intake at work: results from an RCT	N=523; office workers	6 months	Increasing PA, decreasing SB, increasing fruit consumption OR reducing energy intake from snacks	Ecological model	No	5 counseling sessions over 6 months	Pedometers, and educational materials

* BCT = behavior change technique

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CHAPTER 1.

Self-Reported and Objective Sitting Time: Differences by Intervention, Employment Status, and Day of Week

ABSTRACT

Objective: To compare sitting time pre- and post-intervention by employment status and day of week using self-report and objective measures.

Methods: Adults 50 to 70, half employed, were randomized to a "sit less" or "sit-to-stand" condition, wore an ActivPAL for 21 days, and completed the Sedentary Behavior Questionnaire (SBQ) for weekday and weekend at baseline and follow-up. Generalized Estimating Equations explored agreement between SBQ and ActivPAL over time by intervention arm, employment status and day of week.

Results: Participants over-reported sitting on weekdays (β=177.7; SE=42.5, p value<0.0001) and weekends (β=182.7; SE=41.9, p value<0.0001). Those who were employed over-reported sitting on weekdays (β=155.39; SE=94.69, p value<0.1) and weekends (β=180.34; SE=91.10, p value<0.1). Participants over-reported sitting at weekends post intervention (β=127.9; SE=46.6, p value<0.001).

Conclusions: Participants ability to self-assess sitting time was affected by day of week, intervention period and employment. Over-estimating sitting time during an intervention may negatively affect participant motivation.

BACKGROUND

Large-scale epidemiological studies have shown that on average, adults spend approximately six hours of their day sedentary due to workplace environments, travel, and technologies that all encourage sitting [36–38]. Due to the negative health outcomes associated with accumulated sedentary behavior, including increased risk of metabolic syndrome, weight gain, and mortality [39–41], research on sedentary behavior has become increasingly relevant. Sedentary behavior, however, can be a difficult behavior to measure based on its pervasive nature and the amount of behavior accumulated over the course of the day [22,25]. While self-report surveys may include reporting bias, objective measures in large cohorts are not always feasible. Further they are also subject to measurement error due to wear time and processing methods. Hip worn accelerometers have been commonly used to measure sedentary behavior [38]; but current cut point approaches may misclassify low-intensity activities (e.g., standing) as sedentary [28]. Additionally, hip-worn devices (which are normally only worn during waking hours) may have bias in that longer wear times will result in more sedentary behavior and when participants take the device off and they may forget to put it back on. Therefore, current estimates of sedentary behavior calculated by accelerometer cut points may be underestimated due to these measurement limitations. This may mean we are underestimating the relationship with negative health outcomes.

Interventions to reduce sedentary behavior have emerged to address the growing epidemiological evidence of health consequences [34,42–45]. Interventions in workplace settings with environmental changes such as standing desks have shown promise [35,46,47], but these strategies may not be salient for older adults who may be transitioning into retirement and no longer working. Given the large amount of sitting time in older adults, some studies estimating as much as nine hours per day [16], more research in this population is needed.

To assess sedentary behavior objectively, intervention studies consistently use the ActivPAL TM , a new measurement device that uses an inclinometer to detect changes in posture [26,27] . The ActivPAL TM is a thigh-mounted device designed to detect sitting, standing, and stepping [48]. The device is attached to a participant's thigh with adhesive tape and can be worn for 24 hours a day without needing to be removed. The ActivPALTM allows researchers to more adequately capture an individual's entire day. Some studies provide feedback from the ActivPAL TM to participants during behavioral counseling in pilot studies [34,42]. Although participants generally have minimal complaints regarding the ActivPAL TM during these short-term trials, wearing the device long-term may not be feasible due to costs and skin irritations from the adhesives.

Currently, a wearable self-monitoring tool for assessing long-term sitting interventions does not exist. New wearable devices that track activity and provide feedback focus on physical activity and not on sitting. Although participants can wear the ActivPAL TM for short periods and the data from the device can provide feedback on sedentary behavior in the beginning of the study, participants may be expected to self-assess their sitting time for the remainder of the intervention. If participants are expected to self-assess behaviors and report on those behaviors during behavioral counseling sessions with an intervention team, it is important to better understand if there is bias in self-report due to context and participant characteristics. The purpose of this study was to explore differences in self-report and ActivPAL TM measured sitting time by intervention status, measurement period, day of week, and employment status to evaluate participants' ability to self-assess behaviors during a sedentary behavior intervention.

METHODS

Study Design and Procedures

The Take a Stand study was a two-arm randomized-controlled pilot trial funded by the Department of Family and Preventive Medicine at the University of California, San Diego. The study was designed to test the feasibility and acceptability of a short-term sedentary behavior intervention published elsewhere [42]. Thirty participants, equal number of workers and non-workers, were recruited to participate in a two-week sedentary behavior intervention following a one-week run-in period for baseline measurement. Participants were eligible if they were: 1) aged 50-70 years; 2) spent at least an average of eight hours per day sitting over five days; 3) able to attend four measurement visits at the UCSD campus in four consecutive weeks; 4) willing to wear a thigh-mounted inclinometer 24 hours per day for the entire 21-day study duration; 5) able to read and write in English; 6) able to provide written informed consent; and 7) without a serious health condition that would limit their ability to stand. Participants were randomly assigned to either a “sit less” condition where participants were asked to reduce the total amount of sitting time per day by two hours or a “sit-to-stand transition” condition in which participants were asked to add an additional 30 “sit-to-stand” transitions each day.

Measures

ActivPAL™

The ActivPal™ thigh-mounted inclinometer (PAL Technologies Limited, Glasgow, UK) was used to objectively measure sedentary behavior including daily sitting time, standing time, stepping time, and number of sit-to-stand transitions [26,27]. Participants were provided with a waterproofed device and during the first visit they were instructed how to apply the device with adhesive tape. Although participants were provided with replacement sleeves for the device, they were encouraged not to remove the device between study visits to ensure maintained waterproofing during bathing and showering. When participants returned to the office for the weekly visits, they were given a new device for the upcoming week so that the data could be downloaded and feedback provided to participants.

Sleep time hours were removed from these estimates based on a log participants kept to document sleep time and daily waking hours. Because sleep can greatly impact the number of available waking hours for sedentary behavior [26,27], it is important to account for sleep time.

Sedentary Behavior Questionnaire (SBQ).

The SBQ was adapted from a questionnaire used in children that had evidence of reliability and validity [49]. The survey was created in 2010 and asks participants about ten activities they do while sitting or lying down during a typical weekday or weekend day including: 1) watching TV or DVDs; 2) using the computer; 3) reading; 4) talking or thinking; 5) traveling in a car of bus; 6) doing hobbies (e.g., crafts, puzzles); 7) group activities (e.g., meetings, committees, bingo); 8) napping; 9) eating; and 10) any other activities. Participants report time from 10 response categories based on the following values: 0 (None), 1 (less than 30 minutes), 2 (30-60 minutes), 3 (1-2 hours), 4 (2-3 hours), 5 (3-4 hours), 6 (4-5 hours), 7 (5-6 hours), 8 (6-7 hours), 9 (7-8 hours) and 10 (8 or more hours). To calculate SBQ variables, the mid-point of each value (e.g., 6.5 hours for an 8 on the scale) was summed across each of the 10 items separately by either weekday or weekend day as recommended by the original scale creators [49].

Data Analyses

Statistical differences between sitting time from the SBQ and the ActivPAL™ were examined using generalized estimating equations (GEEs) to account for within-person correlations of outcomes at baseline and the final visit. Additionally, GEEs are marginal models and the interpretation of the model is at the population-level without conditioning on specific variables [50]. We stratified by condition because a priori, we hypothesized that participants in the "sit less" condition may self-report sitting time differently than those in the "sit-to-stand" condition because the goal for the intervention was to reduce overall sitting time as opposed to increasing transitions and we wanted to test for potential differences. We chose to stratify by weekday and weekend day because the SBQ asks participants to report sitting time separately across these days and we wanted to further explore these differences statistically by maintaining this distinction throughout the analyses.

First, we explored the overall difference in self-reported sitting time compared to objectively measured ActivPAL™ across weekday and weekend. Next, we tested a method (self-report vs. objective) by employment status interaction stratified by condition and day of week to test if participants' ability to self-assess differed by employment. We then explored if participating in a sedentary behavior intervention changed participants' ability to estimate sitting time by exploring a method by time interaction stratified by condition for weekday and weekend. Finally, after stratifying by condition, we tested an exploratory three-way interaction of method by time by employment status.

RESULTS

Participant Characteristics

A total of 30 participants with an average age of 60 (SD=5.9) who were predominantly female (73%) and White, non-Hispanic (80%) were included in the analyses. At baseline and the final follow-up, self-reported sitting time was higher than objectively-measured time (see **Table 1-1**). At baseline on weekdays, participants self-reported an average 810 (SD=237) daily minutes of sitting compared to the objective ActivPAL™ minutes of 650 (SD=95). On weekends, self-reported sitting time was 747 (SD=279) compared to 583 (SD=143). At the final visit, average self-reported weekday sitting time was around 760 (SD=265) minutes compared to 563 (SD=142) objectively and weekend average self-reported sitting was 741 (SD=221) compared to 538 (SD=134) recorded via the ActivPAL ™. Further descriptive statistics by work status are presented in **Table 1-2**. Similar to the results above, across both weekday and weekend, workers and non-workers over-reported across weekday and weekend.

Results from the Generalized Estimating Equations

There was a significant difference in self-reported sitting time compared to ActivPAL sitting across both weekday (β=177.7; SE=42.5, p value$<$0.0001) and weekend day (β=182.7; SE=41.9, p value$<$0.0001). These results show that participants over-reported almost three hours of additional sitting time across both weekdays and weekend days.

Differences in reporting by employment

There was a significant interaction (p value$<$0.1) for both weekday (β=155.39; SE=94.69, p value$<$0.1) and weekend day (β=180.34; SE=91.10, p value$<$0.1) for method by employment status (see **Table 1-3**). Therefore, the magnitude of the difference between self-reported sitting time and objective minutes as measured by the ActivPAL^{TM} differed by employment status. Full-time employed participants over-reported an additional two hours sitting time on weekdays above and beyond the over-reporting by non-full-time employed participants. On weekend days both full-time and non-full-time employed participants over reported by about 2 hours (see **Figures 1-1 and 1-2**). No significant relationships were found for the "sit-to-stand" condition and are not presented graphically.

Differences in reported sitting time over time during the intervention

There was a significant main effect for method (β=202.6; SE=61.7, p value<0.001) and time (β=-148.1; SE=33.3, p value<0.001) on weekdays for the "sit less" condition (**Table 1-4**) meaning participants over-reported sitting time by more than *three* hours at baseline and had a significant *two* hour reduction in ActivPAL ^{TM} measured sitting time from baseline to the final visit; however, the interaction for method by time was not statistically significant indicating that participants ability to self-assess sitting time on weekdays did not change over time. On weekends, there was a significant interaction (β=127.9; SE=46.6, p value<0.001) in that participants over-reported sitting time on weekends and increased their over-reporting by *two* hours from baseline to the final visit. Therefore, participants' ability to self-report sitting time varied over time by day of week for those in the "sit less" condition (see **Figures 1-3** and **1-4**). In contrast, there was a significant main effect for method in the "sit-to-stand" condition in that participants over-reported sitting time on weekdays (β=194.84; SE=96.4, p value<0.05), but there were no significant interactions for method by time on either weekdays or weekend days. The three-way effect modification for method by time by employment was not significant. Graphs of non-significant relationships are not presented.

DISCUSSION

Despite previous studies in older adults showing issues with underreporting sedentary time [25,51,52], participants in our sample over-reported sitting time at both the baseline and final visit and the difference was significant for both weekday and weekend day. This result could be due to measurement differences in that our scale included two additional items compared to the original SBQ [49] which may have led participants to self-report more time. Or it could be due to the fact that participants were aware that the ActivPAL™ was measuring their sitting time and were therefore more cognizant of overall sitting time and not as influenced by the social desirability bias to present oneself as doing better that is typically seen in self-reported sitting time estimates [51,53].

There was a significant effect modification for employment and time for the “sit less” condition on weekend days. These results indicate that people struggle to report sitting time on weekends when involved in a sitting reduction intervention and when employed. Context and routines likely helps participants self-assess sitting time which is why surveys specifically designed for workers tend to perform well in populations with large amounts of office sitting [54,55]. In contrast, workers may struggle to conceptualize sitting time on weekends because often their behaviors are less scheduled compared to their daily activities during the work week. Ability to self-monitor is affected by daily habits and context which is why workers can more accurately describe their behaviors at work when they tend to be highly habitual [56]. On the weekends, workers do not have the cues to remember the behaviors making weekend time more challenging to self-assess.

The inability to accurately self-assess sitting time on the weekend is problematic because if participants do not think they are effectively changing their behavior, they will not give themselves credit for their success which could negatively impact their motivation to continue to work towards an intervention goal. Furthermore, weekends are still an important target for behavior change as a means to maintain progress and sustain good habits developed during the week. On the other hand, non-workers may not be as tied to environmental cues to trigger their self-assessment of behavior and may not have as much difficulty self-assessing time which is why there were no significant effects in this group. Future studies should continue to explore this relationship in larger samples to better understand how reporting may differ by day of week in workers and non-workers. Additionally, the significant difference in self-reported weekday and weekend sitting time, specifically related to work status, adds justification that self-reported sitting time should be measured separately by day of the week.

There were no significant modifications for method by time or employment status for the “sit-to-stand transition” condition for either weekday or weekend day. This lack of relationship is to be expected as participants in that condition focused on increasing transitions which may not have had an impact on total sitting time, or their conceptualization of sitting time overall. Given that the behavior change was to increase sit-to-stand transitions, participants may not have been conscious or aware of their sitting time because it was not the focus of their goal. It may have been informative to ask participants to self-report their daily transitions before and after the intervention to explore the relationship over time. Participants accrue a large number of transitions over the course of the day, however, and it is unclear how accurately they might report this behavior. Therefore, future studies could investigate whether a self-report item on transitions is valid and reliable and could be deployed to further evaluate this relationship.

Although the three-way interaction of method by time by employment status was not significant in this small sample, further inquiry is warranted. Given that workers over-reported sitting time on weekend days when compared to the ActivPAL™, the same analysis in larger sample of participants may reveal an effect modification that was undetectable in the current study. Survey measures for sitting time in workplaces tend to show promising validity when compared to objective measures [54,55,57], but more research is needed on how survey measures perform in older adults stratified by work status. As older adults transition into retirement, there could be an impact on their ability to record time spent sitting over the course of the day. Additionally, the inverse relationship for workers in that they over-reported sitting time on the weekend should be further explored in a larger sample.

The strengths of the current study include comparison of self-reported sitting time to ActivPAL™-derived time [48,58]. Additionally, the unique population of older adults stratified by workers and non-workers allowed for more thorough exploration into how individuals conceptualize sitting time differently across work status. The present study is not without limitations. The sample size was small and focused on a relatively homogenous group of participants (i.e., mostly white, females) from a pilot study. Future studies could replicate the analyses in a larger, more diverse population to see if the present findings are generalizable.

In conclusion, the present study adds to the research on sedentary behavior assessment in older adults. ActivPALs™ have become the measurement tool of choice for intervention studies and have also been used to generate feedback to participants from the data collected. Despite its utility to provide feedback in the short-term, long-term ActivPAL™ wear may not be feasible, especially in older adults with more delicate skin. Until a suitable intervention tool is developed that accurately measures sedentary behavior and provides feedback to participants, intervention teams may rely on participant self-report during a study. Therefore, this in-depth exploration into how participants conceptualize sitting time is an important step for sedentary behavior interventions and recommends that future studies continue to explore differences in self-reported sitting time by day of week in both workers and non-workers. Finally, because sit-to-stand transitions are a relatively novel behavior, more research is needed on if and how self-report can be used to assess this behavior.

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Table 1-1. Average daily minutes of self-reported and objectively-measured sitting time at baseline and week 2 across weekday and weekend.

Average daily minutes of sitting time	Baseline Mean (SD)	Week 2 Mean (SD)
Sedentary behavior questionnaire		
Weekday	810.0 (236.66)	759.8 (265.17)
Weekend	747.0 (278.78)	741.1 (220.70)
ActivPAL™		
Weekday	650.4 (94.84)	563.2 (142.24)
Weekend	582.7 (143.45)	537.5 (134.00)

Table 1-2. Average daily minutes of self-reported and objectively-measured sitting time at baseline and week 2 across weekday and weekend stratified by work status.

Average daily minutes of sitting time	Baseline Mean (SD)	Week 2 Mean (SD)
Sedentary behavior questionnaire		
Full-time employed		
Weekday	850.7 (200.59)	782.0 (244.90)
Weekend	743.0 (240.79)	770.4 (244.11)
Non full-time employed		
Weekday	772.0 (267.3)	736.1 (292.73)
Weekend	751.0 (320.89)	709.6 (197.24)
ActivPAL™		
Non full-time employed		
Weekday	620.7 (82.18)	548.6(172.85)
Weekend	497.8 (85.14)	490.1 (116.57)
Nonworkers		
Weekday	680.1 (99.92)	578.8 (104.37)
Weekend	667.5 (141.28)	588.3 (136.62)

Table 1-3. Results from the generalized estimating equations exploring method by employment interaction across conditions for weekday and weekend days.

	Weekday		Weekend	
	β	SE	β	SE
"sit less" condition				
Method	153.86*	71.08	127.61*	63.78
Employment	-89.76	52.28	-188.60**	35.53
MethodxEmployment	155.39~	94.69	180.34~	91.10
"sit-to-stand transition"				
Intercept				
Method	66.11	124.27	153.86	71.08
Employment	-83.52	59.43	-89.76	155.39
MethodxEmployment	180.40	137.90	155.39	94.69

*p value<0.05; **p value<0.001; ~p value<0.1

Table 1-4. Results from the generalized estimating equations exploring method by time interactions across conditions for weekday and weekend days.

	Weekday		Weekend	
	β	SE	β	SE
"sit less" condition				
Method	202.6***	61.7	133.8*	54.5
Time	-148.1***	33.3	-84.6*	34.8
Method x Time	50.8	53.9	127.9**	46.6
"sit-to-stand transition"				
Method	194.84*	96.4	122.9	65.2
Time	-3.98	36.1	-23.7	21.4
Method x Time	-58.71	87.8	13.0	86.1

*p value<0.05; **p value<0.01; ***p value<0.001

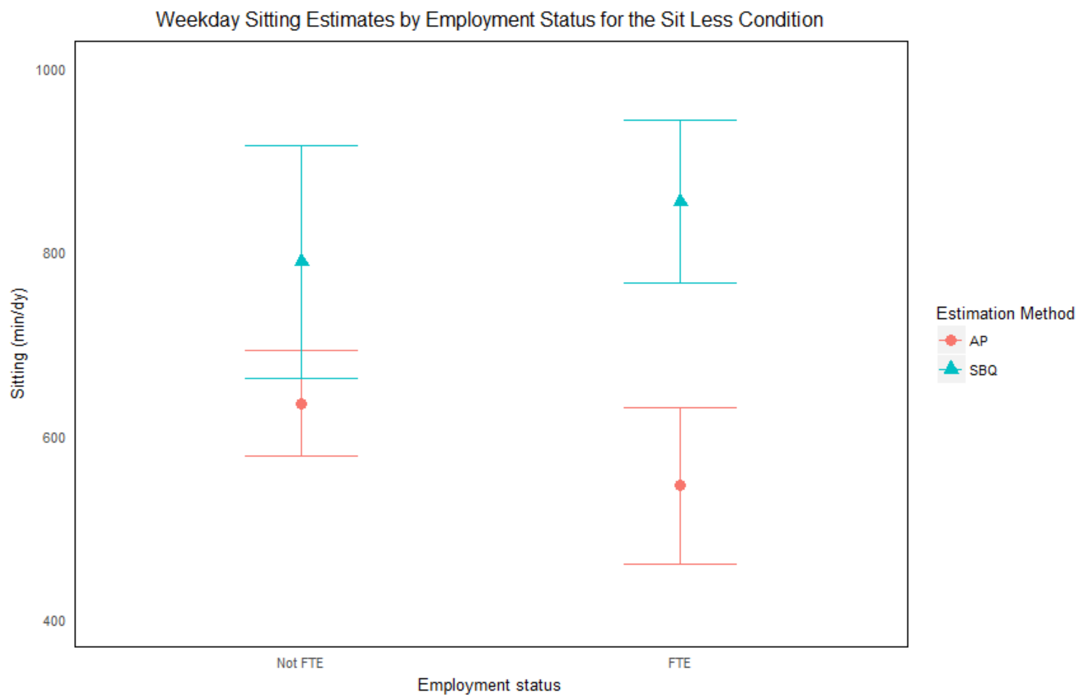

Figure 1-1. Weekday estimates of sitting time for the method by employment status interaction for the "sit less" condition

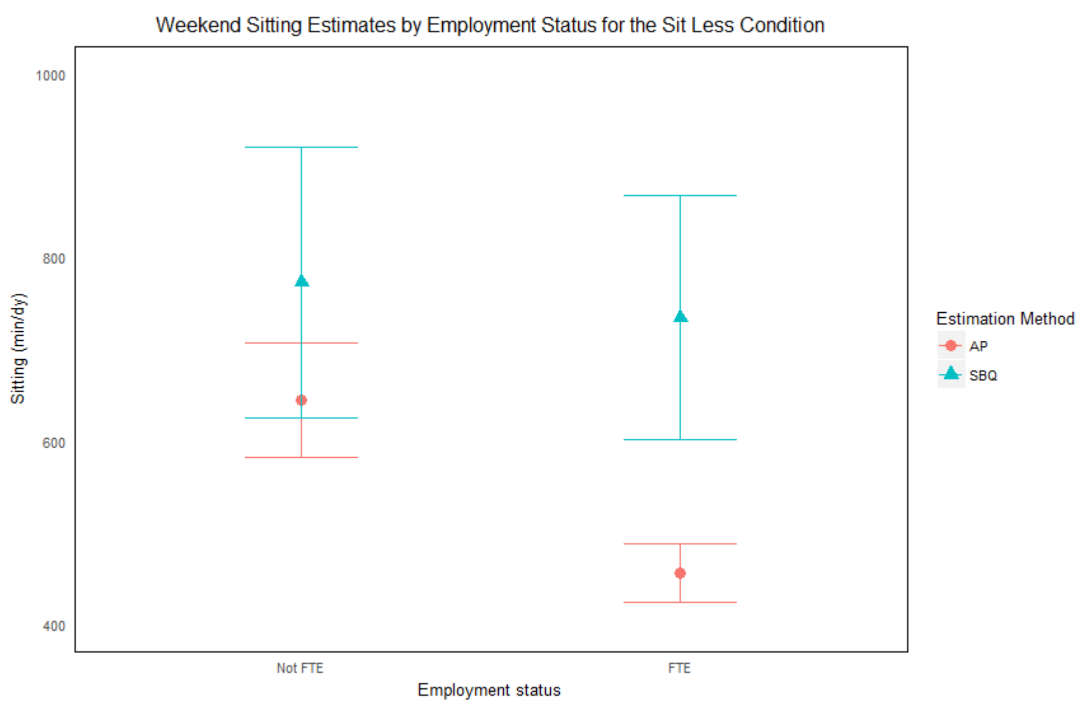

Figure 1-2. Weekend estimates of sitting time for the method by employment status interaction for the "sit less" condition

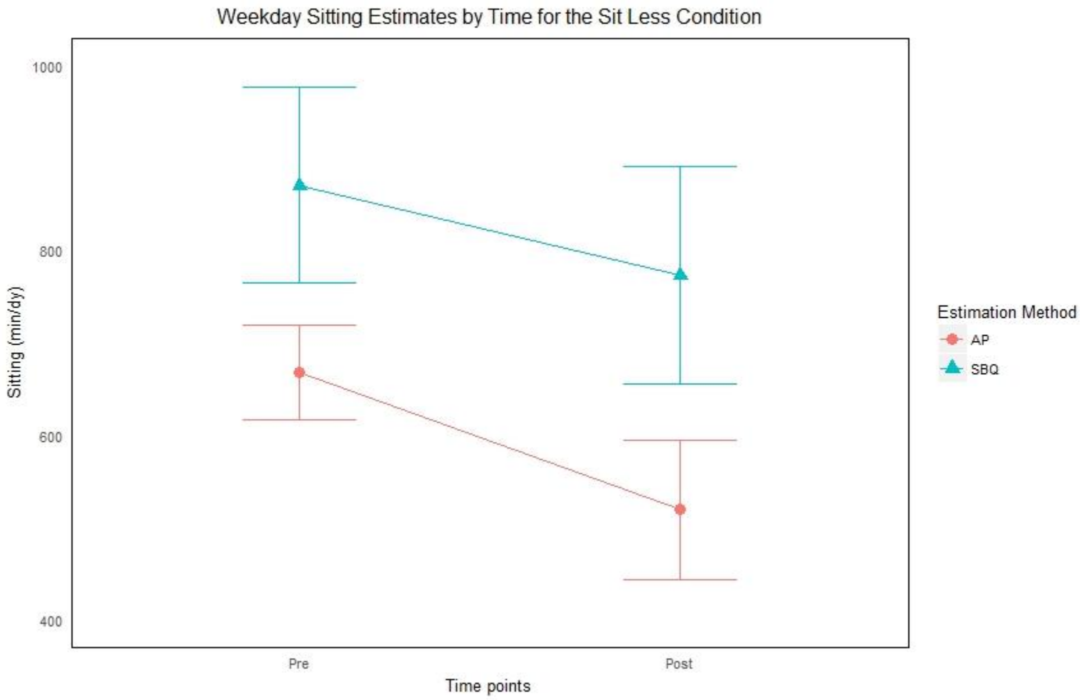

Figure 1-3. Weekday estimates of sitting for the method by time interaction for the “sit less” condition

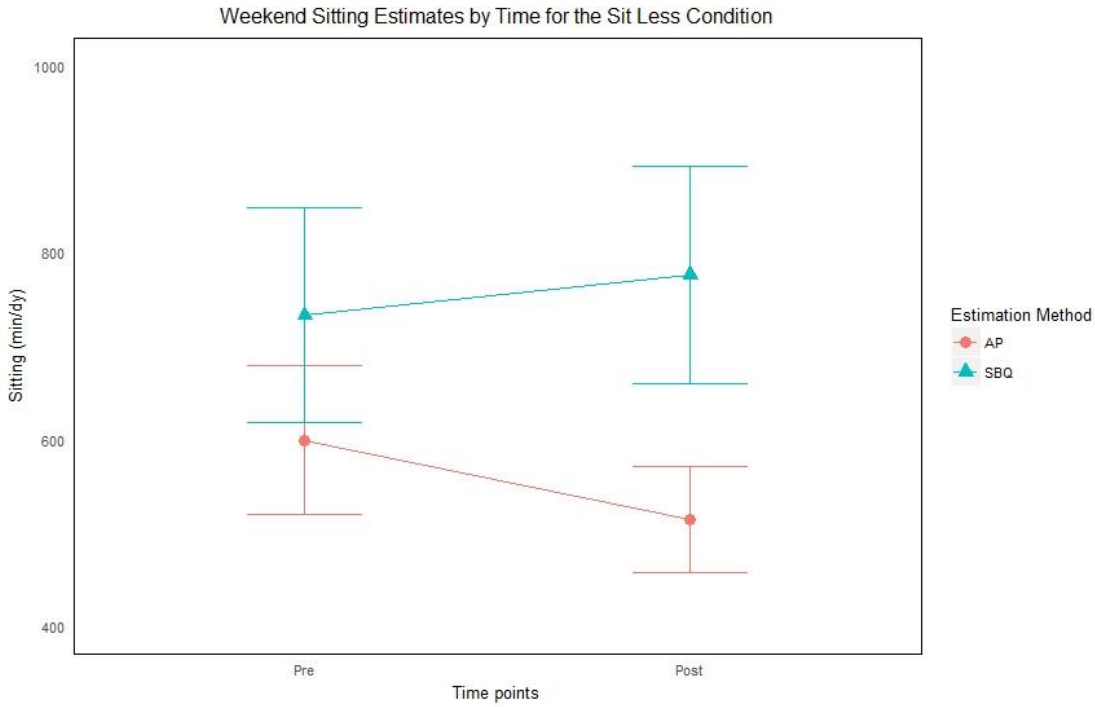

Figure 1-4. Weekend estimates of sitting for the method by time interaction for the "sit less" condition

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CHAPTER 2.

The Search for the Ejecting Chair: A Mixed Methods Analysis of Tool Use in a Sedentary Behavior Intervention

ABSTRACT

Background: Research is needed on interventions targeting sedentary behavior with appropriate behavior change tools because there are negative health outcomes associated with pervasive sitting. The current study used convergent sequential mixed methods (QUAN+qual) to explore how tool use during a pilot intervention impacted sedentary behavior to inform future long-term interventions.

Methods: Data came from a two-arm randomized-controlled pilot trial designed to test the feasibility and acceptability of a sedentary behavior intervention. Participants were presented with a number of intervention tools (e.g., prompts, standing desks, counters). Separate mixed effects regression models explored associations between change in number of tools and amount of tool use with the two intervention targets: change in sitting time and number of sit-to-stand transitions overtime. Qualitative data explored participants' attitudes towards intervention tools and helped explain the quantitative results.

Results: There was a significant relationship between mean tool use and sitting time. With a one-unit increase in frequency of tool use, participants reduced daily sitting time by 75 minutes. However, there were no significant relationships between total tool use and sitting time or sit-to-stand transitions. Twenty-four semi-structured interviews were coded and a thematic analysis revealed 4 themes related to tool use: 1) prompts to

disrupt behavior; 2) tools matching the goal; 3) tools for sit-to-stand were ineffective; and 4) tool use evolved over time.

Conclusions: Participants who honed in on effective tools were more successful in reducing sitting time. Tools for participants to change sit-to-stand transitions were not effective. Devices with real-time feedback that accurately tracks sedentary behavior are needed.

INTRODUCTION

Sitting rates have increased dramatically since the 1960s [59,60]. Prevalence studies estimate that adults spend over 6 hours per day sitting [15,61] while older adults sit more than 9 hours per day [16]. The fact that individuals are sitting more is problematic because recent epidemiological studies have shown that there are deleterious effects of prolonged sitting time including increased risk of weight gain, metabolic syndrome, diabetes, and heart disease [22]. Even more concerning is that these relationships persist even after adjusting for physical activity.

Although research clearly shows a link between total sitting and health, it is still unclear what type of sedentary behavior is most detrimental. For example, recent research has focused on disentangling how the accumulation of sitting time impacts health [62,63]. Specifically, is it overall sitting time, time spent in prolonged bouts of sitting or some combination of these behaviors that has the most direct impact on health? Most of the work focused on elucidating these distinctions has been conducted in the laboratory under controlled conditions. A review in 2015 evaluated the results from 14 acute laboratory studies that compared prolonged sitting conditions with a variety of sitting interruption conditions [64] and the relationship with biomarkers. The review concluded that interrupting sitting time had positive impacts on biomarkers for metabolic risk, especially in individuals who were physically inactive. Additionally, a number of observational studies have also identified this link between breaking up sitting time and health. In a large Canadian Study, an additional 10 breaks from sedentary behavior was associated with more favorable waist circumference, blood pressure, triglycerides, cholesterol, insulin and glucose [65]. In another cross-sectional study, more breaks from sitting were associated with higher fitness scores, even after adjusting for physical activity and total sitting time [66]. Based on these results, it is clear that there are biological benefits to breaking up sitting with standing. Specifically, the physiological benefits from postural changes caused by the action of standing up may have distinct benefits to health that are separate from the physiological benefits associated with physical activity [67]. Given the evidence linking sedentary behavior and health from both laboratory and cohort studies, distinct research is necessary to further explore how to change this behavior in the population.

With the evidence linking negative health outcomes and excessive sedentary behavior [17,38,40,68], there has been a surge of interventions to reduce the behavior. However, changing sedentary behavior can be especially challenging given its ubiquitous nature and the sheer exposure to the behavior individuals are faced with throughout the course of the day [38]. Previously, researchers hypothesized that increasing physical activity through interventions would reduce sedentary behavior as a secondary outcome [69]. A review of interventions by Prince et al. (2014) discovered that an increase in physical activity does not have a direct impact on sedentary behavior [30]. In contrast, interventions focused on changing sedentary behavior by increasing standing have minimal impact on physical activity, but do show promise for reducing sitting time [30,70].

Currently, most sedentary behavior interventions have focused on schools and worksites [71,72] where standing desks are primarily employed. Only a few short-term pilot studies have specifically targeted older adults, with the most successful interventions focusing strictly on changing sedentary behavior and including behavioral feedback from ActivPALs™ or other monitoring devices in conjunction with individual or group coaching [34,43,44,73]. Because most older adults do not work, alternative tools to standing desks require further investigation. Further physical activity studies in older adults have shown that some theory based intervention strategies do not work as well in older adults due to cognitive challenges [74]. Given that older adults struggle to meet physical activity guidelines and accumulate the most sedentary time [75,76], theory-based interventions that target older adults who are both working and non-working.

From physical activity studies we have learned that self-monitoring and cues/prompts are key [31,32,77] and these lessons are being translated into the new area of sedentary behavior reduction. Pedometers are one of the most successful tools in physical activity interventions with real time step counts [78–80]; there is not yet a similar device for measuring sitting that is wearable and appropriate for everyday wear. Despite the surge in wearable activity devices for physical activity (e.g., Jawbone, Fitbit), these devices do not target sitting time specifically and do not register standing as a way to break up sitting time, they only provide feedback when steps are accumulated [81]. Additionally, intervention devices currently available do not accurately measure time spent sitting, standing, or the number of sit-to-stand transitions which are key targets in sedentary behavior interventions [82]. While ActivPAL™ devices worn on the thigh are emerging as the gold standard to assess these key behaviors, and some studies have provided short term feedback from the ActivPAL™ during the intervention, the ActivPAL™ does not yet provide real time feedback on transitions and time in target behaviors.

Specific interventions with appropriate tools to help participants reduce sedentary behavior over longer periods are needed. Qualitative data could help us better understand participants' attitudes to existing tools employed to reduce sedentary behavior [83,84]. Understanding the limitations associated with current tools could drive future development of tools that can specifically target sedentary behavior change. To improve our understanding of behavior change tools employed in sedentary behavior interventions, the current study used a convergent sequential mixed methods approach (QUAN+qual) to explore how tool use during a pilot intervention impacted the targeted sedentary behaviors.

METHODS

Study Design and Procedures

The Take a Stand study was a two-arm randomized-controlled pilot trial funded by the Department of Family and Preventive Medicine at the University of California, San Diego. The study was designed to test the feasibility and acceptability of a short-term sedentary behavior intervention published elsewhere [42]. Thirty participants, with an equal number of workers and non-workers, were recruited to participate in a two-week sedentary behavior intervention following a week of baseline. Participants were enrolled who agreed to participate and met the following inclusion criteria: 1) aged 50-70 years; 2) spent at least an average of eight hours per day sitting over five days; 3) able to attend four measurement visits at the UCSD campus in four consecutive weeks; 4) willing to wear a thigh-mounted inclinometer 24 hours per day for the entire 21-day study duration; 5) able to read and write in English; 6) provided written informed consent; and 7) without a serious health condition that would limit their ability to stand. Participants were assessed by ActivPAL™ for a one-week run-in period for baseline measurement and continued to wear the ActivPAL™ for the remaining two-week intervention. The current study considers the two-week intervention data as tools were only distributed and used during this time. These data were combined with data from the final semi-structured interview because questions from that interview included a section specifically focused on participants' tool use.

Participants (N=30) were randomly assigned to either a "sit less" condition where participants were asked to reduce the total amount of sitting time per day by two hours or a "sit-to-stand transition" condition in which participants were asked to add 30 sit-to-stand transitions each day. We chose to focus on a two-hour reduction in sitting because we wanted to test whether or not we could replicate similar findings found in previous trials [33] in a population of middle aged and older adults who were both working and non-working. Sit-to-stand transitions were targeted separately because previous studies had not succeeded in increasing this behavior, probably because they had focused on increasing standing which reduces the number of sit stand opportunities. We hypothesized that focusing solely on frequent transitions would be more effective and potentially have different health impacts [67] when compared to prolonged standing. The intervention components were developed to emphasize Abraham & Michie's 26-item behavior change taxonomy [31,32] and included constructs such as goal setting, feedback, prompts and cues, and self-monitoring which have been shown to be important in previous interventions. Unlike the intervention paper that reported on the main effect of a significant behavior change compared to baseline [42], the current study focuses on the intervention weeks only as There was significant behavior change compared to baseline; this study focuses on the intervention weeks only and the tools employed because tools were only distributed and used during that time.

Participants came in for study visits each week during the pilot (see **Table 2-1**). During each weekly session, participants in both conditions met with a health educator to review their sedentary behavior from the previous week focusing on either total sitting time or sit-to-stand transitions, depending on condition. The data from the ActivPALs™ were processed to provide participants with a daily break down of their sedentary behavior over the course of the previous week (see **Figures 2-1 and 2-2**). This allowed participants to develop a plan to accomplish the goal based on their routines. With the health educator, participants developed an appropriate action plan to incorporate into the following week to work towards the goal. The participants discussed strategies to either reduce their sitting time or increase sit-to-stand transitions based on their routine and regular activities.

Participants in both conditions were provided with a variety of tools to support the distinct goals that targeted the aforementioned behavior change constructs including self-monitoring and prompts/cues [31,32]. Individuals in the “sit less” condition were provided with 13 tools that were a combination of physical tools or virtual reminders and included:

standing desks, program timers to disrupt sedentary behavior (e.g., smartphone apps, computer program apps), physical timers that could be placed in a variety of locations (e.g., work desk, on top of TV, kitchen counter), a vibrating watch, a branded study bracelet with the study tagline, a bookmark and card with the study logo and description, notepad and dry erase board to write notes, and reminders via various communication mediums such as text messages, emails, or phone calls from study personnel to work on the behavior change. Participants in the "sit-to-stand transitions" condition were instructed that the transitions could be brief as a means of avoiding interrupting normal activities. Participants in this condition were provided with the same tool choices as the "sit less" condition and were also provided with an electronic counter to track the number of transitions taken throughout the day. Because the transitions were designed to be brief, they were not provided with standing desks.

Measures: Quantitative Data: ActivPAL™

The thigh-mounted inclinometer called the ActivPAL™ (PAL Technologies Limited, Glasgow, UK) was used as the primary objective measure of sedentary behavior for the entire pilot intervention. The ActivPAL™ detects daily sitting time, standing time, stepping time, and number of sit-to-stand transitions [26,27]. To omit sleep time from these measures, participants completed a log to document sleep time and daily waking hours. Because sleep can greatly impact the number of available waking hours for sedentary behavior [26,27], it was important to analyze sedentary behavior changes while accounting for sleep time. Participants were provided with a waterproofed device and during the first visit they were instructed how to apply the device with adhesive tape. Although participants were provided with replacement sleeves for the device, they were encouraged not to remove the device between study visits to ensure maintained waterproofing during bathing and showering. When participants returned to the office for the weekly visits, they were given a new device for the upcoming week.

Quantitative Data: Tool Usage Questionnaire

After each intervention visit, participants completed an interviewer-administered tool usage survey (see **Table 2-1**). The survey was designed to explore how often participants used the tools throughout the course of the intervention week. Participants rated how often they used specific tools based on response categories with values including 1 (“Never”), 2 (“Once”), 3 (“A few times”), 4 (“Everyday”), and 5 (“Multiple times per day”) for each tool available. A total of 13 tools were available.

Two constructs related to the tools were important, the number of tools taken and the frequency of tool use. The interviewer completed a checklist with participants assessing how many tools were taken to use and how often the tools were used at each time point. The number of tools taken was summed, ranging from 0 to 13. Total tool use was calculated by summing how often any of the 13 available tools or prompts were used ranging from 2 (“Once”) to 5 (“Multiple times per day”) across only the tools participants reported using during the intervention weeks. Mean tool use was calculated by dividing total tool use by the number of tools taken. Therefore, a participant who reported using a high number of tools infrequently would have a high value for total tool use, but a lower value for mean tool use. A participant who reported using only one tool, but used that tool multiple times per day would have a lower total tool use score but higher mean tool use.

Qualitative data: semi-structured interviews

Following the interviewer-administered tool-usage survey at the end of each intervention week (see **Table 2-1**), participants took part in a semi-structured interview to discuss their experiences during the previous week while working towards the sedentary behavior goal. This study focused only on data from the final interview because it included questions about each of the tools available during the intervention. First, participants were asked “what strategy or strategies helped you the most” and “what tools helped you the most” to explore if there were any strategies or tools outside of the ones provided within the intervention that helped participants with the goal. Then, the interviewer asked participants about each of the tools provided by the research team to see if the participant had tried the tool during the intervention and why or why not. Finally, participants were asked to design a “magic tool” that would help the most with accomplishing the intervention goal. The purpose of these questions was to learn more about what tools may have been especially effective compared to those that were not. Additionally, the interviews were used to explore potential themes related to tool use for the specific behaviors (i.e., sitting less, increasing sit-to-stand transitions).

Mixed Methods Data Analyses

We used a sequential convergent (QUAN+qual) mixed methods approach to explore participants’ experience using tools to change sedentary behavior[85,86]. Using a mixed methods approach allowed for further understanding regarding not only what tools were effective, but why certain tools were more effective than others and how tool use changed over time throughout the intervention. Mixed method analyses aimed to provide a more comprehensive understanding of how participants effectively used tools to change sedentary behavior.

Part 1 - Quantitative analysis and results

All analyses were conducted in R and began with mixed effects regression analyses over time, with days nested within participants. Separate models explored the association between change in tool use with change in sitting time or number of sit-to-stand transitions stratified by intervention condition across the intervention weeks. Each model included a random slope for tool use variables and random intercept to account for clustering among observations within people and their individual sedentary behavior change trajectories. The residuals for the sit-to-stand transitions models were skewed; therefore, the variable was log transformed in each model.

A total of 30 participants were included in the analyses who were primarily female (73%) and White, non-Hispanic (80%) with an average age of 60 (SD=5.9). For the "sit less" condition, the most commonly used tools during the first week were the branded study bracelet, physical timers, and emails; however, in the second week, physical timers were one of the least popular tools and instead, most participants continued to use the bracelet and reminder emails or a standing desk. For the "sit-to-stand transition" condition, the tally counter and physical timers were the most popular tools across both weeks. Participants used the bracelet more the first week and reminder emails were the most popular communication medium for prompts the second week (see **Table 2-3**). Tool use changed across weeks in both conditions (see **Table 2-3**). For the "sit less" condition, number of tools was 3.33 (SD=1.63) week 1 and 2.93 (SD=1.94) week 2 and for the "sit-to-stand transition" condition, number of tools was 3.07 (SD=1.62) week 1 compared to 2.93 (SD=1.83) in week 2. Total tool use was 12.67 (SD=0.78) for week 1 and decreased to 12.00 (SD=0.60) in week 2, but mean tool use was 3.80 (SD=0.78) for week 1 and increased to 4.15 (0.60) in the "sitting less" condition. In contrast, total tool use and mean tool use increased in the "sit-to-stand transition" condition from 10.07 (SD=0.63) for total tool use and 3.54 for mean tool use (SD=0.63) in week 1 compared to total tool use of 11.60 (SD=0.57) and mean tool use of 3.84 (SD=0.57) in week 2.

Results from the mixed effects regression analyses found a significant negative relationship between *mean* tool use and sitting time indicating more consistent tool use, regardless of number of tools used, was associated with decreased sitting time. With a one-unit increase in mean tool use from intervention week 1 to week 2 (e.g., increasing from using a tool everyday to using it multiple times per day), participants reduced sitting time by 75 minutes per day. In contrast, there were no significant relationships between number of tools or *total* tool use and sitting time indicating that if participants used a higher number of tools or used more tools there was no impact on outcomes (see **Table 2-4**). There was no significant difference between number of tools, *mean* tool use, or *total* tool use and sit-to-stand transitions.

Part 2 - Qualitative analysis and results

Following the quantitative analyses, the semi-structured interview data were used to further explore participants' attitudes towards intervention tools and explain the quantitative results; specifically, to further understand why tool use differed across conditions and to explore the lack of association between number of tools used and any sedentary behavior. A priori hypotheses were that participants would increase the number of tools used from visit 3 to visit 4, but the analyses revealed that number of tools remained relatively stable across visits. Therefore, we wanted to understand this finding that was contrary to our hypotheses. Additionally, we wanted to better understand why there was an association between increased mean tool use and sitting time, but a similar finding was not present for mean tool use and sit-to-stand transitions.

A structural coding approach guided the thematic analysis with the interview questions driving how codes were applied to provide a more structured process. Interviews were recorded and the lead author reviewed each interview to code for content and pull out relevant codes. The process began with an initial cycle of open coding to identify segments of data related to tool use. Reviewing the interviews assisted in refining the number of overall codes by grouping them into descriptive categories that were appropriate for final analysis. Saturation was determined when no additional information was presented and no new codes were generated from two interviews. To confirm saturation, a final two interviews were coded with no new codes generated. A total of 24 interviews were coded and a thematic analysis revealed 4 overall themes related to how tool use evolved over the course of the intervention including: 1) prompts to disrupt behavior; 2) tools matching the goal; 3) tools for sit-to-stand were ineffective; and 4) tool use evolved over time.

Prompts to disrupt behavior

Participants consistently reported prompts were an effective strategy to change behavior; how participants preferred the prompts to be delivered varied. For some participants, prompts from a computer app or via email were effective because they spent most of their time at a computer which made the prompts accessible. Other participants used physical timers as prompts because they were not always at a computer or near their phone. Smartphone apps were effective for some participants, but other resisted any phone-based prompts because they "didn't like to be so attached to a phone." Across the board, participants continued to reflect on the usefulness of timers to cue behavior change because as one participant stated, "reminders are important even if you're doing something you like" and either do not want or intend to change.

Tools matching the goal

The standing desk for the sit less group was especially effective and some participants reported it was all they needed to accomplish the behavior. Participants who opted for the standing desk reported it was extremely useful in helping them accomplish the goal to sit less. According to one participant, once she used the standing desk, she "did not need any additional tools." In contrast, for participants in the sit-to-stand condition, some participants reported that the computer app timers were ineffective because they prompted participants to stand for extended periods of time as opposed to simply transitioning from sitting to standing which was the goal of the study.

Tools for sit-to-stand were ineffective

The majority of tools available for participants in the sit-to-stand group were mostly ineffective. Participants were satisfied with the timers, but were frustrated by the frequency with which they continued to have to set the timer. For example, if participants wanted to achieve the goal of adding an additional 30 sit-to-stand transitions per day, they would need to set a timer to prompt them approximately every 20 minutes. For some participants, this was burdensome and unrealistic. Additionally, for participants who tried the electronic counter, some participants reported frustration with the device because not only were they required to set a timer to remind themselves to stand up, but they also needed to remember to count the stand by pressing the counter. Ultimately, it was too many tasks to remember and participants were frustrated with the amount of work required. Also, although the device itself was on a small lanyard, the lanyard length was too small to allow participants to wear it as a necklace and too big to wear around the wrist; this prevented participants from fully integrating the tool into their daily lives.

Tool use evolved over time

Some participants reported taking too many tools in the first week and not using most of them. When they identified a tool that worked, they used that tool more frequently during the week and did not need to use any additional tools. Additionally, participants reported that tools that worked in certain environments were not effective in other environments. For example, computer prompts were helpful while at work, but participants needed to use a different tool to work on the behavior at home. Participants also discussed that tools needed to be convenient and fit into their daily routines. Some participants liked the physical timers, but did not feel comfortable using them in all situations. Participants who worked in an office setting did not want to use the timers because the noise might disrupt other coworkers.

Magic tool

There were a variety of responses when participants were asked to design the “magic” tool to help them change their behavior. Some participants wanted the ActivPAL^{TM} itself to vibrate as a prompt to stand up (now available in some models) while others preferred a wrist-worn device. Several participants envisioned an “ejecting chair” or some device that would physically force people out of the chair and into a standing position. One participant would have even opted for an electric shock as a reminder to stand. A television prompt that would pop up while watching a show to remind participants to stand was also an option. Several participants wanted the magic tool to also provide feedback regarding progress. Getting real-time feedback from a device that was always with them would be especially helpful because "it's important to be reminded all day long." Therefore, participants wanted a tool that would work in all environments to make it easier to work on the goal continuously throughout the course of the day.

DISCUSSION

With the evidence surrounding the negative effects associated with sedentary behavior, new interventions to reduce and interrupt time spent sitting have become an important public health focus. By combining qualitative and quantitative strategies in a mixed methods approach, this study adds breadth and depth to help elucidate the context behind successful tool use to change sedentary behavior [87,88]. The present study is the first to conduct a more thorough analysis of participant tool use specific to a sedentary behavior intervention that featured two distinct behaviors (i.e., sitting less, increasing sit-to-stand transitions). A mixed methods analyses allowed for further exploration into understanding not only ***if*** (i.e., quantitative results) tool usage impacted outcomes, but ***why*** (i.e., qualitative feedback).

Based on the quantitative analysis, participants who used fewer tools, but used those tools more frequently were better able to reduce their sitting time. After exploring the qualitative data, the reasoning behind this relationship became more evident. Participants continuously reported that they did not need multiple tools; instead, they tended to rely on one tool and use that to work on the goal. However, it was difficult for participants to predict which tools would be most effective before trying out the behavior, so providing a menu of tools to choose from was especially important. Given the novelty of the behavior, participants needed to experiment with tool options before honing in on which tool would be the most effective for them.

Tool use and preference varied dramatically across participants and across environments. Although participants consistently preferred prompts, how those prompts were delivered differed. Some participants preferred physical timers while others only needed a computer prompt to remind them to stand and others relied on their smartphones. Providing different options is important to ensure participants find a method that works the best for them. Going forward, a tool that could be worn continuously (i.e., wearable device) might be especially valuable because participants would have access to the tool in all situations which would allow them to continuously work on the behavior change. This result further justifies a recommendation from a recent review by Martin et al. (2017), which recommended developing technologies that allow people to monitor their sedentary behavior to support them in sitting goals [70].

The Take a Stand pilot was the first study to explore sit-to-stand transitions as a specific behavior change goal. Based on feedback from participants, current tools available for this behavior were lacking in utility and were generally ineffective. Prompts available for sedentary behavior specifically focus on displacing sitting with more prolonged standing and are inappropriate for increasing the number of sit-to-stand transitions which would break up sitting more frequently Further, the multiple posture changes may have effects on key biological systems. Additionally, given the high number of transitions participants need to achieve throughout the day to shorten prolonged sitting bouts (e.g. every 20 minutes), trying to monitor this behavior continuously is extremely taxing. The electronic counters provided by the study were irritating for participants because they could not fit them into a daily routine. Having to remember to record the transitions was also a deterrent to using these tools. Although the ActivPAL™ feedback provided during the health coach session was helpful for participants, this information was not provided real-time and the feasibility of using an ActivPAL™ long-term is unclear based on costs (if participants kept devices more devices would be needed per study and each device is costly) and wearability (some participants may experience skin irritations from the thigh adhesives). It is unclear what types of tools will be most effective in targeting this behavior. Previous studies have shown that self-monitoring and goal-setting are key constructs [43,44,89]. Therefore, future sedentary behavior tools should not only monitor amount of sitting time, but also record the number of sit-to-stand transitions to test this as a mechanism to impact some biological outcomes.

The strengths of this study include the combination of methods to explore which tools were helpful and why for reducing sedentary behavior. Given the recent surge in interventions to change sedentary behavior [70,71], a thorough exploration into how tools can be used to target important behavior change constructs, specifically, self-monitoring and cues, is especially valuable and can provide information for future intervention development. Limitations of the current study include a small sample size of mostly White, non-Hispanic females. Additionally, because we wanted to target both working and non-working adults, our sample of participants aged 50 to 70 years may not generalize to the population of older adults at large. Future studies should explore long-term tool use in a larger population of more diverse individuals to increase generalizability.

Implications

Researchers: The population at large is becoming increasingly sedentary. With research showing negative effects of this behavior on health, developing effective intervention strategies should be a public health priority.

Practitioners: It is unclear what method of breaking up sitting is most beneficial; however, the clear association between sitting and health merits increased attention. Healthcare providers should provide information about this important health topic to older adults but be aware of the challenges in changing this very habitual behavior.

Policymakers: Some organizations have health guidelines that include general statements about reducing sitting. More specific behavior targeting is necessary to improve health and clear long-term behavior change techniques for this behavior outside of work or school settings are not yet available. Investigating in research that focuses on the systems influencing sedentary behavior should be a priority.

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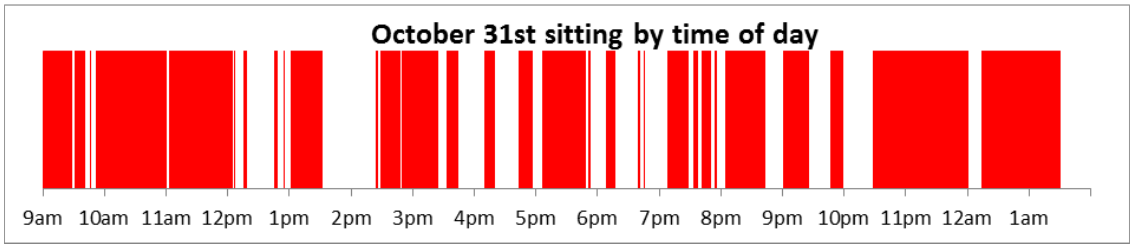

Figure 2-1. Sample feedback graph for "sit less" condition. Red indicates extended bouts of sitting.

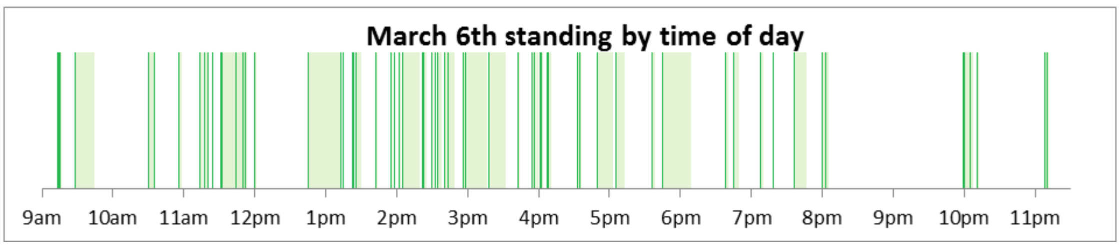

Figure 2-2. Sample feedback graph for "sit-to-stand transition" condition. Green indicates a sit-to-stand transition.

Table 2-1. Timeline of study activities in the Take a Stand Intervention

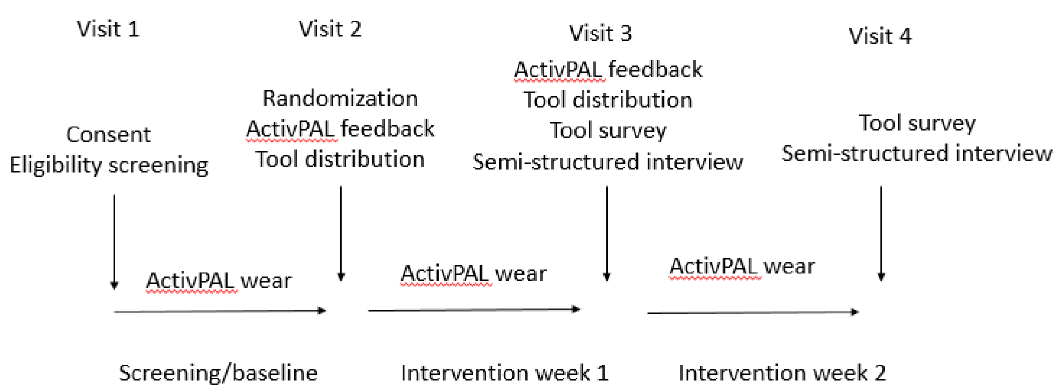

Table 2-2. Number of participants who used the tool each week in both conditions

	Sit less		Sit-to-stand transitions	
	Week 1	**Week 2**	**Week 1**	**Week 2**
Intervention tool				
Participants who used tool [N (%)]				
Standing desk*	6 (40)	8 (53)	--	--
Tally counter**	--	--	7 (47)	9 (60)
Smartphone applications with reminders to stand	2 (13)	1 (6)	2 (13)	2 (13)
Computer programs with reminders to stand	4 (26)	4 (26)	5 (33)	5 (33)
Watch timer	1 (6)	1 (6)	0	0
Physical timer	8 (53)	3 (20)	6 (40)	6 (40)
Notepad	1 (6)	1 (6)	1 (6)	2 (13)
Bookmark	3 (20)	2 (13)	1 (6)	1 (6)
Text messages	1 (6)	2 (13)	1 (6)	2 (13)
Emails	8 (53)	10 (67)	5 (33)	7 (47)
Phone calls	3 (20)	1 (6)	3 (20)	2 (13)
Study bracelet	9 (60)	7 (47)	7 (47)	5 (33)
Card with study description	2 (13)	3 (2)	1 (6)	0
Dry erase board	0	0	4 (26)	1 (6)

*Only working participants in the sit less condition were provided with standing desks

**Only participants in the sit-to-stand condition were provided with tally counters

Table 2-3. Descriptive statistics of tool use and sedentary outcomes at intervention weeks 1 and 2 (N=30).

	Week 1 Mean (SD)	**Week 2** Mean (SD)
Tools		
Sitting less group		
Number of tools	3.33 (1.63)	2.93 (1.94)
Total tool use	12.27 (0.78)	12.00 (0.60)
Mean tool use	3.80 (0.78)	4.15 (0.60)
Sit-to-stand transitions condition		
Number of tools	3.07 (1.62)	2.93 (1.83)
Total tool use	10.07 (0.63)	11.60 (0.57)
Mean tool use	3.54 (0.63)	3.84 (0.57)
ActivPAL™ outcomes		
Sitting less group		
Minutes of sitting time	639.0 (154.94)	518.6 (161.59)
Sit-to-stand transitions	45.11 (18.56)	45.07 (17.77)
Sit-to-stand transitions group		
Minutes of sitting time	610.2 (128.35)	595.9 (152.82)
Sit-to-stand transitions	56.54 (24.97)	77.24 (54.11)

Table 2-4. Association between change in number of tools and frequency of use with change in sedentary behavior outcomes (i.e., sitting time, sit-to-stand transitions) from intervention week 1 to week 2 (n=30).

	Daily minutes of sitting time		**Daily number of sit-to-stand transitions**	
	Coefficient	SE	Coefficient	SE
Number of tools	19.00	10.75	0.01	0.04
Total tool Use	1.49	2.49	0.003	0.01
Mean tool use	-75.40	27.51*	0.01	0.19

*p value>0.05, **p value>0.001; Fully adjusted models were adjusted for ActivPAL™ wear time.
SE: Standard Error

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CHAPTER 3.

STAND UP! A Qualitative Analysis of Participants' Perceptions on the Use of Technology to Reduce Sitting Time

ABSTRACT

Background: Recent epidemiological evidence indicates that on average, people spend approximately 7.7 hours per day sedentary. There are deleterious effects of prolonged sedentary behavior (SB) that are separate from participation in physical activity and include increased risk of weight gain, cancer, metabolic syndrome, diabetes, and heart disease. Wearable devices are being used to increase physical activity in studies; however, additional research is needed to fully understand how this technology can help reduce sitting time. The purpose of the current study was to explore the usability and acceptability of wearable devices to change sedentary behavior through a general inductive analysis of focus group discussions.

Methods: We conducted 4 focus groups with a total of 15 participants to discuss 7 different wearable devices with SB capabilities. Participants recruited for the focus groups had previously participated in a pilot sedentary behavior intervention targeting sedentary behavior over a 3-week period so were knowledgeable about the challenges of reducing sitting time. During focus groups, participants commented on the wearability, functionality, and feedback mechanism of each device and then identified their two favorite and two least favorite devices. Finally, participants were asked to design and describe their ideal or "dream" wearable device.

Data Analysis: Data from the focus groups were coded and analyzed by two researchers (MT, BL) who have expertise analyzing qualitative data. A thematic analysis approach using Dedoose software (Version 7.5.9, 2016) guided the organization of themes that reflected participants' perspectives.

Results: Analysis resulted in 14 codes that were grouped into themes. Three themes emerged from our data: 1) Features of the device; 2) Data the device collected; and 3) How data are displayed.

Conclusions: Current wearable devices for increasing physical activity are lacking in key features to target reducing sitting time. This was especially evident when participants were asked to vote as several participants reported using a "process of elimination" as opposed to choosing favorites because none of the devices were ideal for reducing sitting time. Based on the limitations in current devices, future wearable devices designed to reduce sitting time should include the following features: waterproofing, long battery life, accuracy in measuring sitting time, real-time feedback on progress towards sitting reduction goals, and flexible options for prompts to take a break from sitting.

INTRODUCTION

Given the recent surge in epidemiological and laboratory studies highlighting the association between excessive sedentary behavior and poor health outcomes, new interventions to reduce sitting time are necessary[18,19,90]. One of the many challenges associated with reducing sitting is its ever-present nature and the sheer volume individuals accumulate throughout the day. Based on the continuous exposure to the behavior, trying to measure how much time individuals spend sitting can be extremely challenging. Therefore, regular monitoring via technology to reduce participant burden may be an especially valuable intervention tool.

Technology as an intervention tool has been used effectively in physical activity research. Based on the clear positive benefits associated with increased physical activity[91,92], decades of previous research have identified goal setting and self-monitoring as successful intervention strategies to increase physical activity [91]. Pedometers have continuously been identified as a powerful change tool that can motivate individuals to increase physical activity[78,80,93]. Pedometers are helpful tools in that they allow participants to self-monitor behavior by tracking the number of steps taken throughout the course of the day[94]. Additionally, new wearable devices, such as Fitbits, are based on the same principles as pedometers and combine self-monitoring with individual feedback on participants' progress towards goals[95,96]. Therefore, wearable devices provide an effective strategy for increasing physical activity by allowing for tailored goal setting and serving as reinforcement to work towards a specific goal[80].

Although wearable devices have been shown to be effective strategies for increasing physical activity[95,96], it is still unclear how technology might be applied to sedentary behavior. One potential strategy involves the use of smartphone applications. A recent study capitalized on the surge in mobile applications focusing on health-related outcomes including physical activity and sedentary behavior[97]. The researchers employed a "just-in-time" intervention strategy to provide participants with real-time feedback regarding their activity. However, a limitation of smartphone apps to change sitting time is the likelihood of misclassifying standing as "inactivity" based on a phone's location. If a participant puts the phone on a desk while they take a standing break, the accelerometer in the phone would fail to capture this behavior as standing and would instead classify it as inactivity. For a participant working towards a goal to reduce sitting, this misclassification can be frustrating and may demoralize his/her drive to work towards accomplishing the goal. Current wearable devices that focus on prompting participants to move more are not designed with a focus on reducing sitting; however, use of such devices to target this behavior could be especially valuable if developers could overcome these measurement limitations given the difficulty for individuals to monitor sitting time and the ubiquitous nature of the behavior.

Therefore, a wearable device that mimics the features of a pedometer by tracking accumulated sitting time and accurately measures sitting time to prompt behavior change throughout the course of the day (e.g., vibration, alarms) could be an especially effective intervention tool given wearable devices success in physical activity interventions[78–80]. Given the rapid innovations in wearable technology combined with the negative health outcomes associated with prolonged sitting, this study used a focus group methodology to explore the usability and acceptability of wearable devices to change sedentary behavior.

METHODS

The research was guided by a general inductive approach in that data collected were used to describe results related to wearable devices and sedentary behavior. Focus groups were used because they provide a fast and efficient method to obtain information from multiple participants[98]. Additionally, the group setting can prompt conversations between participants around ideas which yields more in-depth data that may be missed in one-on-one interviews[98].

PARTICIPANTS

Participants were recruited from a previous sedentary behavior intervention. The Take a Stand study was a two-arm randomized controlled pilot trial funded by the Department of Family Medicine and Public Health at the University of California, San Diego. The study was designed to test the feasibility and acceptability of a short-term sedentary behavior intervention. Full description of the study is provided elsewhere[42]. Briefly, 30 participants between the ages of 50 and 70 years, with an equal number of workers and non-workers were followed for 21 days while the intervention was delivered. Participants were eligible if they were: 1) aged 50-70 years; 2) spent at least an average of eight hours per day sitting over five days; 3) able to attend four measurement visits at the UCSD campus over four consecutive weeks; 4) willing to wear a thigh-mounted inclinometer 24 hours per day for the entire 21-day study duration; 5) able to read and write in English; 6) able to provide written informed consent; and 7) without a serious health condition that would limit their ability to stand. Upon enrollment, participants were randomized to either a decrease sitting or an increase sit-to-stand transition condition. Participants were asked to work on either sedentary behavior goal over the course of two-weeks while wearing a thigh-mounted inclinometer called the ActivPAL™ which objectively measured sedentary behavior. The device did not provide real-time feedback on the behavior, but participants retrospectively viewed the past week's progress during weekly intervention visits.

Qualitative research often focuses on participants who are likely to provide rich information about the specific research questions[99]. Therefore, we used a purposive sampling technique[100,101] to include participants from the Take a Stand study because these individuals had previous experience attempting to change their sedentary behavior and interacting with the ActivPAL™ which is considered a wearable sedentary behavior device. Therefore, their feedback was more informed based on their prior exposure to both sedentary behavior interventions and devices designed to record activity.

Focus Group Overview

Four focus groups were conducted in September 2014 and each lasted two hours. The groups were stratified by work status (i.e., worker or nonworker) and intervention condition (i.e., sit less or increase sit-to-stand transitions). We chose to stratify to elucidate information about how wearable devices might work best depending on the participant's work status and intervention goal. Previous sedentary behavior interventions have focused primarily on worksites and we wanted to explore how participants might favor wearable devices differently depending on work status. Additionally, given the novelty of the sit-to-stand transition behavior, we wanted to better understand how current wearable devices could be used for this type of behavior. Therefore, we chose to have separate focus groups to reflect the differences we anticipated. There were between two and five participants per group, depending on participant availability.

The research team began by identifying wearable devices to include as examples in the focus groups. Current wearable devices focus primarily on physical activity (i.e., steps), but some devices also collect data on sedentary behavior (i.e., inactivity, sitting). We also wanted to include devices that had different wear locations (e.g., wrist, back, thigh) to enhance variability. We included seven devices with varying features in the discussion: the ActivPAL™, SitFIT, LUMOback, Smart Move shoe insert, Sensoria Sock, Garmin Vivofit, and Jawbone UP (see **Table 3-1**).

The purpose of the focus groups was to discuss the usability and acceptability of wearable devices specifically focusing on wearability, functionality, and interfaces of devices. Given previous research using wearable devices to change physical activity, we hypothesized that similar devices could be especially effective tools to help reduce sitting time and we wanted more information from participants regarding the acceptability of current devices on the market. The moderators for the focus groups (JK and KC) have experience with sedentary behavior research and were involved in the Take a Stand pilot; JK was the principal investigator and KC was the project manager. However, neither JK nor KC had prior participant interaction during the intervention study so they could serve as moderators who were unfamiliar to the participants to allow participants to be as open as possible.

Prior to beginning the focus groups, participants provided written informed consent and the moderators stressed the confidential nature of the discussions. Participants were informed that the discussion would be transcribed in real-time via a transcriptionist, used for research purposes only, and would not be accessible to anyone outside the research team. To ensure confidentiality, participants were asked not to use their full names. To encourage open communication of thoughts and ideas, the moderator stressed that the opinions of each participant were important and there were no right or wrong answers. Upon completion of the focus groups, participants were thanked and provided with $20 as compensation for their participation. All study activities were approved by the Institutional Review Board at University of California, San Diego (UCSD).

The first part of the focus groups focused on wearability and functionality of each device. Each participant received a packet with information about each device that would be covered during the session. The packet included pictures and descriptions of each specific device. To get started, the moderators introduced each device to the participants including a brief description of features and then gave each participant the opportunity to hold the device and see it up close. The moderators then asked participants to describe any benefits or barriers to using the device for an extended period (i.e., six months).

The first device discussed was the ActivPAL^{TM} device which participants wore for three weeks during the previous pilot intervention and had experience in using this device. We then moved on to the remaining six devices. Participants were probed with questions to determine which device they thought would be the most useful in reducing sitting time during a six-month intervention. Questions included “what do you foresee as the biggest challenge to wearing this device for a long-term intervention?” or “what feature of this device do you think will be the most helpful?”

The next section of the focus group focused on the interfaces (i.e., the medium used to display data to users) for the current devices. To begin, moderators provided a brief overview about interfaces and how they can be used to provide feedback about one’s behavior. Some of these interfaces were displayed via a smartphone or computer and others were found directly on the device itself. The next section focused on discussing the current interfaces available and identifying the pros and cons of each. Sample questions included: “which do you like the most and why?” and “what do you like least about this interface?" After discussing each interface, participants rated their most and least favorite interfaces.

After having the opportunity to discuss each device, participants were given the opportunity to vote on their favorite device. Specifically, when voting, participants identified their two favorite and two least favorite devices by weighing the pros and cons of each device based on their individual preferences. During the final part of the focus group, participants were asked to design an ideal device. This ideal device would incorporate the pros and cons of each of the previously described devices and interfaces, but it could also include features that do not exist in these devices that would be essential to helping individuals reduce their sitting time or increase sit-to-stand transitions. Participants were given an opportunity to be creative by drawing the device and describing what features it would include. When designing the focus group protocol, we consulted with a colleague who works in the field of human computer interaction research which is the study of how people interact with computers and other technology. The voting and device design sections of the focus group were based on previous work with user experience design which emphasizes involving the end-users in the initial design process to ensure products are developed that fit user needs [102]. Additionally, we purposely maintained a small number of participants per focus group to ensure participants had ample opportunity to interact with each of the 7 devices and participate fully in the voting and design portions. Similar to product testing with consumer companies, we recruited a smaller number of informed participants per group to collect more detailed information regarding the usability and acceptability of these devices to change sedentary behavior.

Data Analyses

Each session was transcribed in real-time by a transcriptionist who was present during the entirety of each session. To facilitate transcription, participants sat behind numbered placards allowing the transcriptionist to note who was speaking. Transcripts were analyzed by two researchers (MT, BL) who have experience coding qualitative data and had worked on the Take a Stand study. MT is a doctoral student at University of California, San Diego and has obtained formal training in qualitative and mixed methods research. BL has earned a Master's degree in Public Health, has experience with qualitative research methods, and was an integral part of the Take a Stand study. MT developed the focus group guide and BL served as a device expert during two of the focus groups. Neither MT nor BL were involved in the moderation of the focus groups.

A thematic approach guided data analysis and data were organized into themes that reflected participants' perspectives. All analyses were carried out using Dedoose software (Los Angeles, CA: SocioCultural Research Consultants, LLC). First, each coder read the transcripts independently. They began with an initial read through to familiarize themselves with the content. During the second read through, each coder took notes and highlighted significant passages. The first transcript was coded in Dedoose together by MT and BL to create an initial codebook. Segments of the content with similar meaning were assigned to the same code. The remaining transcripts were used to refine the concepts of the initial codebook and combine the codes into key themes. When new codes or themes emerged, the codebook was revised and the previous transcripts were re-coded. Because coding occurred in tandem, any discrepancies were resolved in real-time and ensured that all transcripts were coded by both researchers. Coding occurred over the course of several months and saturation was reached when no new codes were generated after a final review of the transcripts. Key quotes were selected that were representative of the main themes.

RESULTS

A total of 15 people participated across the four focus groups with the largest group having five participants and the smallest group having two participants. Given the highly interactive nature of the focus groups, we purposely recruited smaller sample sizes per group. Based on the older population and because we were seeking such detailed information about the 7 devices, the smaller size groups were viewed as an advantage by allowing participants to stay engaged and interactive with the information we were asking them to comment on. The average age was 59 and 87% were female (see **Table 3-2**). The majority (80%) were White non-Hispanic and there was an almost equal distribution between work status and condition (53%). From the 14 codes analyzed (see **Table 3-3**), three overall themes emerged related to the pros and cons associated with different aspects of the devices: 1) features of the device; 2) data the device collects; and 3) how data are displayed.

Features of the Device

Participants reported mixed feelings about the various features of each device. Some participants liked devices that were directly adhered to the body because they were never forced to remember to put on the device; however, other participants commented that they would not wear an adhered device long-term (e.g., ActivPAL™). Participants were concerned about the pocket-worn SitFit device because as one participant described "most of the pants I wear don't have pockets." They would be more likely to use the device if they could attach it to a belt that could be worn with all pants. However, other participants had no concerns with the pocket placement and could easily incorporate it into their daily lives.

Aesthetics of the device were important both for device look (i.e., did the device come in different colors [e.g. Jawbone & VivoFit]) and for how the device would fit into an everyday routine. For example, participants struggled to understand how they could incorporate the Sensoria sock device or SmartMove shoe insole into everyday routines because not all outfits required a sock or tennis shoes. One participant wore “sandals all the time” and another participant reported being “barefoot most of the time” which meant the form and location of these devices would make it challenging to wear consistently. Although this was likely a San Diego warm weather bias and might not be an issue in other areas with different climate. During the “dream” device design portion, participants ideally wanted a wear location that could be flexible depending on what they needed for specific days. For example, as one participant described “my ideal device would be kind of adjustable, depending on what you're going to wear and maybe on your back one day or your leg…whether that be [adhered with] some kind of adhesive…or a belt so it can be interchangeable.” Another preferred wear location was the wrist.

Feedback was an important feature and participants wanted control over how often the feedback was delivered. Most participants requested real-time feedback (e.g., Jawbone UP, SitFIT) as a method to actively work towards the goal throughout the course of the day. Prompts were another desired feature and again, participants wanted control over type of prompt (i.e., vibration [Jawbone], visual [Vivofit]) and frequency (i.e., ability to deactivate prompts during sleep hours or change prompts depending on work schedule). When designing the “dream” device, participants emphasized the importance of programmability to allow everyone to choose feedback and prompts that were the most relevant and helpful to them as individuals. A participant said, “the frequency of the feedback would be programmable by the individual.”

Practical features such as battery life and waterproofing were also mentioned. Longer battery life (e.g. Vivofit) was a benefit for several participants as it eliminated the need to remember to charge the device frequently. Finally, whether or not a device was waterproof (e.g. Vivofit) and could be worn in the shower thereby not requiring participants to remove the devices and subsequently remember to put the device back on (e.g., Jawbone, Lumoback, SitFIT) impacted participants’ willingness to use the device long-term. When describing their “dream” devices, participants highlighted the importance of these practical features of the device when designing a device for long-term use.

Data the Device Collects

Participants were concerned about device accuracy to detect sitting time and preferred devices that provided information on sitting time as opposed to inactivity. As mentioned previously, most current wearable devices focus on inactivity and thereby classify both sitting and standing as inactivity (e.g., Jawbone, Vivofit). However, other devices (e.g., ActivPAL, SitFit, Lumoback) are specifically designed to measure sitting and standing as separate behaviors and participants favored the devices that were able to accurately distinguish between sitting and standing. Additionally, some participants doubted a device’s accuracy based on where the device was worn (e.g., pocket where the

SitFIT was worn or wrist where the Vivofit and Jawbone were worn were seen as less accurate). As one participant described it when designing the “dream” device, “It has to track sitting. It has to track sitting to standing based on the goal.”

Participants were mixed on the amount of information different devices collected. For example, some people liked the idea of collecting additional information (e.g., sleep, posture, calories) while other people were concerned that by collecting more information, there would be more opportunity to question the accuracy of the data collected. As one participant described “there's more to question when you get a lot of data…If it thinks that I'm driving three hours, but I really only drive one hour but I rode my bicycle two hours, and it's confusing bicycling with driving, I might say to myself, Oh, this isn't accurate…I will lose confidence with the accuracy of the device.” Devices that were not able to detect sit-to-stand transitions (e.g., Jawbone UP, Vivofit) were viewed less favorably by participants from the sit-to-stand transition condition. Control over data which allowed participants to choose how the data are displayed and who can access the data was a priority with one participant stating “I’d rather have control…, even [if the device is] not comfortable, than no control over something like data.”

How Data are Displayed

Participants had varying opinions on where and how the data should be displayed. Some participants liked data displayed on a smartphone (e.g. Jawbone, LUMOback) while others were adamantly against it because they did not own a smartphone and had no plans to purchase one anytime soon. One individual talked about the need to “get away from the phone” which was a barrier to any device tied to a smartphone display. Participants also liked the idea of displaying long-term data on a computer to allow them to see “the progression of change over time.” Frequency of feedback also varied as some participants wanted to see progress throughout the course of the day while others would only want to see if every few days or weekly. Whatever medium was used, participants wanted the data displayed to specific to sedentary behavior. The devices that only displayed information related to activity or inactivity were considered less than ideal given the focus on sedentary behavior. Participants preferred interfaces with data displayed in a way that was “easy to understand,” provided a quick summary of overall behaviors, used a combination of graphs, charts, and images, and were visually appealing. Additionally, if the interface used colors to represent behaviors, participants commented that the colors should be intuitive. For example, if they were focusing on reducing sitting with standing, time spent sitting should be highlighted in red and standing should be represented with green. One of the featured interfaces had reversed these colors and participants felt this was counterintuitive and confusing. As described by one participant “it’s very dumb.” On the contrary, interfaces that had a lot of information with small font, a busy display and required “too much reading” were viewed negatively. Flexibility was highlighted again when participants were designing “dream” devices as participants emphasized that “everybody is different” and being able to modify how the data are presented would be a key feature of the ideal wearable device.

Voting

Across the four focus groups, the most popular device was tied between the SitFIT and the Jawbone UP/Vivofit with 11 ‘favorite’ votes for each and the least popular device was the Sensoria Sock/SmartMOVE with 10 ‘least’ votes and the Lumoback received 8 ‘least’ votes. One theme that arose from this portion of the focus group was that participants had a difficult time choosing favorites because none of the devices were perfect. As one participant described, “I was sort of doing a process of elimination more than I was activity voting for the favorites.” However, the votes reflected the themes because the SitFIT and Jawbone UP/Vivofit were specific to detecting sitting time, did not require charging and had prompting capabilities. While the Sensoria Sock/SmartMOVE LUMOback were good at detecting sitting versus standing or posture, the wear location was not functional for long-term use.

DISCUSSION

As the evidence around the negative health effects associated with increased sedentary behavior continues to emerge, interventions to reduce this behavior are becoming increasingly important. Wearable devices represent a novel method to intervene on sitting time given their numerous features that aid in behavior change including real-time feedback and prompts to interrupt the behavior. However, there has been limited research highlighting the usability and acceptability of these devices in sedentary behavior interventions. Furthermore, most of the current devices on the market are designed with physical activity as a primary focus and an emphasis on encouraging movement. Therefore, it is unclear how these devices could be used effectively in sedentary behavior research. The present study is one of the first to more thoroughly explore the barriers and benefits associated with existing wearable devices to reduce sitting time using feedback directly from participants who have intimate experience trying to change this behavior.

Overall, participants were amenable to using technology to change behavior; however, a major limitation of the current devices available was the focus on movement or inactivity as opposed to sitting or standing and that few devices collected information on sit-to-stand transitions. As one participant described it, by not focusing on sitting time, the device would fail to get a “reduction in sitting time.” Given that participants frequently commented that feedback is a critical component necessary to change behavior, devices that do not provide feedback on the specific behavior would not be effective.

Another key finding is that flexibility across all features (e.g., wear location, prompting, feedback) is essential. A common theme across all focus groups was that everybody is different. For example, some participants thought a wrist-worn device would fit perfectly into their daily routine while others would never wear such a device. Some participants only wanted to view data via a smartphone while other participants would never view data on their phone. Additionally, practical features of devices (e.g., waterproof, battery life) were especially important. Therefore, the design of future wearable devices for sedentary behavior should highlight flexibility and functionality as much as possible to strengthen buy-in from users.

Our study is not without limitations. Specifically, the sample size was small and the majority of participants were female and white, non-Hispanic. However, their experience from the previous pilot intervention enabled them to have a more informed perspective on the barriers and benefits to using wearable devices to reduce sitting time which attenuated this limitation. Also, given the interactive nature of the focus groups, we purposely chose to limit number of participants to allow for a more thorough exploration into each device. Additionally, participants only had experience using the ActivPAL™ device for an extended period of time and did not have the opportunity to try the other wearable devices. Future research could have participants try each device for a longer period of time to get more information on how the device may or may not fit into the everyday routine. The strengths of our study include the use of qualitative methods to gain more insight into the feasibility of using wearable devices to reduce sitting time. Although we stratified by work status and intervention condition, the themes were consistent across focus groups further strengthening the applicability and generalizability of the results.

CONCLUSIONS

Evidence shows that excessive sedentary behavior is unhealthy. Wearable devices represent a novel intervention tool targeting sedentary behavior that has the potential for large scale dissemination and impact. Overall, these devices are viewed as usable and acceptable to participants; however, current wearable devices on the market lack a specific focus on sedentary behavior and are thereby inefficient in targeting behavior change. Therefore, new research that specifically addresses sedentary behavior is needed to push the field forward. Furthermore, given the high variability in desired features, feedback and location, research that involves the end user in the design is needed.

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Table 3-1. Features of the wearable activity trackers reviewed during the focus groups

	ActivPAL	SitFIT	LUMOback	Vivofit Jawbone UP	Sensoria Sock and SmartMove
					
Wear location	Thigh	Pocket	Lower back	Wrist	Foot and ankle
Feedback display	Paper graphs	Device, Smartphone, web	Smartphone	Smartphone, Web Sync with plug	Smartphone, web
Frequency of feedback	Delayed until visit with study staff	Real-time	Real-time	Real-time	Real-time
Prompt type	Vibration	Vibration	Vibration	Red bar vibration	Unknown
Prompt programmable				X	Unknown
Tracks sitting				Inactivity	Potentially
Tracks sit to stand				X	Potentially
Tracks steps					
Tracks sleep	X	X			X
Tracks other	None	None	Posture	Calories, distance	Speed, calories, altitude, distance, cadence
Waterproof	With tape and supplies	X	X		Washable
Battery life	~12 days by staff	Unknown	Up to 7 days	1 year 7 days	Unknown

Table 3-2. Descriptive statistics for participants in the focus groups (n=15)

Characteristic	N (%) or Mean (SD)
Age	59 (6.21)
Gender	
Female	13 (87)
Race	
White, non-Hispanic	12 (80)
Condition	
Sit Less	8 (53)
Work status	
Full-time employed	8 (53)

Table 3-3. Themes/codes and seminal participant quotes

Theme/Code		Participant Seminal quote
Features of the device		
Battery life	How long the device is able to work without charging; how is the device charged	
Pro		And I also like the fact this one has a year battery as opposed to this one which as seven days.
Con		That's one of my biggest -- one of those -- one of my biggest testing out all kinds of things, you have to remember to plug them in the middle of the night. And if forgot not, you kind of messed up your study. And it's just I like not having to worry about plugging them in weekly and whatever. Something's were every night you'd have to remember to plug it in and that's a pain.
Comfort	How comfortable the device would be to wear (i.e., size of device, bulk, weight, how device affixed to body)	
Pro		The tape didn't bother me, you know, it was comfortable.
Con		I'm not wearing this piece of rubber. It would be real uncomfortable.
Wear location	Where the device is worn	
Pro		And I'm better with things that are stuck to my body. I don't have to deal with it or remember using.
Con		My pockets on shallow. My lipstick, my Kleenex. I probably could get it in the other pocket, but see I'd be really worried that I'd lose it.
Aesthetics	How the device looks (i.e., color)	
Pro		I like the fact that it's got different colors. I like the black.
Waterproof	Whether or not the device is waterproof	
Pro		I'm glad to hear that it's waterproof. Because I always have my hands in water so it seems like they're always getting wet.
Con		My only problem would be I go to the ocean all the time. Would it get in the way of the ocean?
Prompts	Whether or not participants would have control over type of prompt (i.e., visual vs. tactile) and when device prompts (i.e., during waking hours)	
Pro		And I need that little reminder that I've been sitting too long. Because I read a lot. So and I can get carried away reading and a good two hours, I haven't moved. So I need a reminder to get up and move.
Con		I'm afraid I wouldn't see the red line. I think I would need the vibration or something. When I get business busy, I don't know that I would notice.

Table 3-3. Themes/codes and seminal participant quotes (Continued)

Theme/Code	Participant Seminal quote
Features of the device	
Feedback	Ability to receive real-time or instant feedback (if desired) and control over frequency of feedback
Pro	“That's more helpful to than anything to remind me to get up all during day and the evenings. The evening is my biggest problem. So something like that where I saw, well, I have 30 in by the end of the day, but I also need to be thinking about the evening too.”
Con	There's not really instant feedback that I should have unless have you an iPhone with you.
Data device collects	
Accuracy	How accurate the device would be to classify behaviors (i.e., sitting, standing)
Pro	FACILITATOR KC: Accuracy is really important. PARTICIPANT: That's the only question I have.
Con	PARTICIPANT 83: The other thing is that I really use my hands a lot to talk. PARTICIPANT 61: You know, I could run three miles just in a conversation with my hands. It detects your hand movement.
Control over data	Who owns the date (i.e., UCSD vs. private company) and whether or not participants or study have control over how the data are displayed and reviewed
Pro	I’d rather have control over something, even though it's not comfortable than no control over something like data.
Con	The Garmin, I really, really, like. I just -- I don't like other countries being able to track my data.
Information device collects	What type of data device collects/measures (i.e., sitting, standing, stepping, sit-to-stand transitions, calories)
Pro	That's nice that it incorporates both of them, the steps and the sitting cause I've worn a pedometer for a long time for another study and I just kept wearing it. It would be nice to have more things incorporated into one. If you're going to have to keep up with something, have as much info as you can.
Con	The whole sitting for periods of time is kind of what attracted me to this so if you don't have a way to track that it's like -- probably wouldn't buy one.

Table 3-3. Themes/codes and seminal participant quotes (Continued)

Theme/Code		Participant Seminal quote
How data are displayed		
Data displayed on device	Device itself features a data display	
Pro		That's more helpful to than anything to remind me to get up all during day and the evenings. The evening is my biggest problem. So something like that where I saw, well, I have 30 in by the end of the day, but I also need to be thinking about the evening too.
Con		That was actually my first response when I was through the -- pressing the buttons to seeing the different functions, I can't see it. I know something's there.
Data displayed on computer	Ability to review data on computer	
Pro		I think it's more feasible on a day-to-day basis to see that instant feedback as you're moving throughout the day because you're so busy then to have to go to your phone for something else or your computer. But the long term, when you have time and get to see and track your resulted, I think [a computer] would be awesome.
Con		PARTICIPANT 17: Not a computer. That's too bad.
Data displayed on Smartphone	Ability to review data on smartphone	
Pro		I would like something that could interface with like an iPad or an iPhone or something like that so I could see -- and just see it. I'm just visual so I want that.
Con		I am a cave woman. I do not have a smartphone, and I have immediate plans to buy a smartphone. So something that had an interface or feedback on a smartphone would not work for me
Interface	How the information is displayed on the interfaces (i.e., bar graphs, charts, words) including how helpful the data are for understanding behavior (e.g., colors represent behaviors, summary of activities, ability to quickly understand outcomes)	
Pro		Easy that, you know, you can look at it easily and see what's going on. It's easy to read.
Con		This one I selected, it's too busy, too condensed, and also they may a mistake. To me it's very dumb to have [red] stand [for standing] and [green] standing for just the opposite [sitting].

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DISCUSSION

This dissertation provides an in-depth exploration into sedentary behavior specifically focusing on older adults. The study included three components: 1) a quantitative analysis comparing self-reported sitting time to objectively-measured time; 2) a mixed methods analysis exploring how tool use during a sedentary behavior intervention impacted outcomes and changed over time; 3) a qualitative analysis of focus group data evaluating the potential for wearable devices to help change sedentary behavior. By combining methods, results from the aforementioned chapters provide breadth and depth that pushes the field forward towards a more thorough understanding of sedentary behavior. Three themes emerged from this dissertation related to sedentary behavior and include specificity of measurement, intervention, and technology. Taken together, the results from this work provide recommendations to improve the field by using specific measures for sitting time to capture differences across the week, designing interventions to include tools with a specific focus on sedentary behavior, and exploring how technology can be used to change behavior.

SPECIFICITY OF MEASUREMENT

Chapter 1, *Comparison of Self-Reported Sitting Time to Objective Data from a Thigh-Mounted Inclinometer*, described the comparison of self-reported sitting time to objectively-measured time via ActivPALs™ from participants in a sedentary behavior intervention. Self-report may be the most viable measurement option for large-scale cohort studies, but it is unclear how these surveys perform in intervention trials. Although surveys specifically related to sitting time during work hours appear to perform relatively well [54,55,57], these measures likely will not translate to non-working populations. Context may play a major role in how participants self-assess sitting time. During old age, most individuals typically transition from working full-time to retirement; therefore, these context-based measures may be less relevant to individuals who do not have a consistent work routine. Additional research is needed to explore how older, non-working adults conceptualize sitting time across the week. Furthermore, results from Chapter 1 indicate that workers may underestimate their success in reducing sitting time on the weekends; this could have important implications because longer interventions may rely on participants to assess their success throughout the course of the study. If participants do not think they are accomplishing the goal, even when the objective measures indicate they are, their motivation may suffer and they may become discouraged and overwhelmed. Better understanding in regards to how workers conceptualize sitting time on weekends is needed.

SPECIFICITY OF INTERVENTION

Based on the review by Prince et al. (2014), it is clear that to effectively change sedentary behavior, specific interventions must be designed with a sole focus on reducing sitting time without including a goal to increase physical activity [30]. In a review in 2015, Gardner and colleagues identified behavior change strategies [31,32] that show the most promise in sedentary behavior interventions for adults [71]. The interventions that had a strong theoretical foundation and included several constructs tended to have the biggest impact on outcomes. The constructs that had the most effect were self-monitoring, problem solving, modifying the social and physical environments, and providing education about the behavior. A major limitation for intervening is that sedentary behavior is innately habitual. Research has shown that habitual behaviors may require even more cues and it is still unclear what types of tools are the most effective for changing sedentary behavior [89]. Chapter 2, *The Search for the Ejecting Chair: A Mixed Methods Analysis of Tool Use in a Sedentary Behavior Intervention*, described how tool use during a short-term sedentary behavior intervention evolved over time and provided recommendations for future interventions. Given the habitual nature of sedentary behavior, participants in the intervention relied on cues and prompts to remind them to work towards the goal. It could be that participants need additional support from multiple tools early in the intervention when they are first working on the behavior change; once they have a better understanding about how to change the behavior, the reliance on these tools may decline. Interventions should provide participants with an array of tools to choose from while they hone in on the tool that works the best for them given their specific needs.

Another benefit of providing participants with a menu of tools is that different tools may be more effective in different environments. For example, although standing desks were a popular tool for working individuals, these devices are only applicable for part of one's routine and do not help an individual work on the goal throughout the course of an entire day. Therefore, tools that transition from work to home are needed to help individuals continue to work towards the goal at all times. Results from Chapter 2 emphasize that more research is needed regarding effective tools that target brief sitting interruptions such as sit-to-stand transitions. Given the potential impact on health from these frequent postural changes [67,103] and that these behaviors may be more feasible for older adults compared to trying to achieve the recommended amount of moderate-to-vigorous physical activity [8], increasing this behavior in this population could have major impacts on health.

SPECIFICITY OF TECHNOLOGY

Interventions with a strong focus on technology have emerged as innovative strategies to change behavior. Physical activity interventions with wearable devices as intervention tools that include self-monitoring have been shown to be effective [95,96]. Given that sitting is a pervasive behavior, pervasive sensing through technology could be an effective intervention strategy. Chapter 3, *STAND UP! A Qualitative Analysis of Participants' Perceptions on the Use of Technology to Reduce Sitting Time*, used qualitative data from focus groups to explore participants' insight into the wearability and acceptability of current wearable devices for sedentary behavior interventions. Findings from the study indicate that despite their potential for behavior change, current wearables are not sufficient for sedentary behavior because they do not accurately measure sitting, standing, or sit-to-stand transitions [81] which are key targets for sedentary behavior. The ActivPAL™ can measure these behaviors correctly and new models are available with a vibrating prompt to interrupt sitting. Additionally, these new models are Bluetooth capable to allow for real-time feedback which is an important feature for participants. In spite of these new features, it is unclear how effective these new ActivPALs™ will be for older adults based on issues related to smartphone usage and limited battery life. Furthermore, the ethics of this type of pervasive sensing must be considered. Therefore, additional research is needed to identify how best to capitalize on technology to intervene on prolonged sitting.

FUTURE DIRECTIONS

The work from this dissertation has helped launch new projects. Based on my work on the Take a Stand pilot, I was a lead contributor to a Program Grant submission to National Institutes on Aging to explore sedentary behavior in post-menopausal women. The program grant includes three separate studies and the clinical study is a 4-arm randomized-control trial that includes a “sit less” and “increase sit-to-stand transitions” condition in a larger sample (N=592) for 12 weeks. Additionally, our group received funding from the American Heart Association (AHA) to conduct a large-scale sitting reduction intervention in post-menopausal Latinas (N=250). Upon successful completion of this dissertation, I will serve as the post-doctoral research scholar for that study. From my work on the original pilot, I was intimately involved in adapting the original intervention materials to this new population. One of my first tasks as a post-doctoral scholar will be to write a manuscript describing the adaptations that were largely determined as a result of my work on this dissertation.

Results from Chapter 1 helped us choose to use the Sedentary Behavior Questionnaire [49] in our survey and specifically include separate questions for weekday and weekend. I plan to conduct a similar analysis on the results from this larger population of Latinas to further explore how self-reported sitting time compares to objectively-measured time in a sitting reduction intervention. Further understanding of tool use as explored in Chapter 2 led us to identify an alternative tool that is similar to a standing desk that can be used in participants’ homes. Because the standing desks were so popular in the previous pilot, we knew we needed to provide something similar to this new population; however, the population of older, post-menopausal Latinas may not be working and we had to find a tool that could be used outside a worksite setting. The "standing tables" look more like a piece of furniture and provide a surface for participants to do other activities (e.g., read, write, eat) in an upright position. Self-monitoring continuously emerged as a key construct across Chapters 2 and 3 of the dissertation. Participants from Chapter 2 were amenable to the use of technology to change behavior and several participants liked the idea of a wrist-worn device that provided continual feedback. Given these findings, we are including the Jawbone UP in our American Heart Association study as a mechanism for participants to keep track of time as they work towards the goal. Additionally, the results from the focus groups in Chapter 3 helped us to better frame the limitations of the device in regards to standing. Because the device only monitors inactivity and cannot distinguish between sitting and standing [81], we are coaching participants to consider it an extra accomplishment if the device vibrates when they are already standing. We recognize that participants may get frustrated if the device prompts them to stand when they are already standing so we modified how we presented the tool to participants to overcome this weakness. Recognizing the device's limitations, but still including a tool for self-monitoring was necessary to target this important behavior change construct and ensure participants have a method for self-monitoring until a more effective tool is developed. The results from this dissertation have been incredibly beneficial during the development and launch of this new project.

FUTURE DIRECTIONS FOR THE FIELD

Sit-to-Stand Transitions

As the number of older adults continues to grow [1], it is imperative that researchers continue to identify strategies to promote healthy aging across the lifespan. Given the functional limitations associated with increasing age that may limit the ability to accomplish the recommended physical activity guidelines [8], the need to identify more feasible interventions that could impact health has become especially relevant. Interrupting sitting time represents a novel behavior change strategy that could have major health impacts in this growing population. More research is needed to understand how brief sitting interruptions, such as sit-to-stand transitions, may impact overall health. Results from our pilot show that participants can feasibly accomplish this behavior change in the short-term, but longer studies are needed in larger populations. Even without adequate tools and support, participants were still successful in changing behavior. If evidence can link these short transitions with health, it could have dramatic impact on older adults' well-being. Large-scale cohort studies are needed to explore the association between sit-to-stand transitions and health; however, a limitation is that accelerometers alone and self-report cannot accurately measure these behaviors. Therefore, large epidemiological studies must include ActivPALs™ to detect these postural changes and push the field forward. The ability to get up out of a chair is an indicator for functional independence and maintaining this ability should be a priority through continued research into the health impacts of increasing sit-to-stand transitions.

Self-Monitoring and Prompts are Key

Previous research in multiple behaviors including physical activity has found that self-monitoring is a key construct for behavior change [31,32]. Currently, there is no self-monitoring tool for sitting. Given the ubiquitous nature of the behavior and the fact that society at large is become even more sedentary [12,104], new research into effective self-monitoring tools is necessary. Without proper tools to self-monitor behavior, individuals will continue to struggle to self-assess and this inability makes behavior change even more challenging. Additionally, based on the habitual nature of sedentary behavior, prompts are especially important [71]. The type of prompt could vary depending on the environment, but interventions should capitalize on the benefits of prompts as a method for breaking up sitting.

Worksite Versus Home Environment

Previous research has shown that sitting reduction in worksites are largely effective [35,47,105] and self-report surveys that measure sitting time in worksites have performed with reasonable accuracy [54,55]. Interventions to change workplace sitting have targeted multiple levels of the ecological model to improve effectiveness [47]. Office computers can be programmed to include prompts to break up sitting along and environmental changes to include the addition of standing desks all paired with organizational support from upper management, have shown promise in reducing office sitting time. A major limitation of these types of worksite interventions is that they only target part of a participant's life and more research is needed on how to effectively intervene across the week and in the home. Many older adults may be transitioning from full-time employment into retirement and this stage of life could present an important opportunity to intervene. The habits individuals develop while working could transition with them into retirement and intervening at this pivotal moment could have lasting impacts on health. Identifying methods to intervene in the home while capitalizing on successful strategies that break up sitting at work in this population of transitional individuals could be an especially effective strategy. Developing comprehensive interventions that translate across the spectrum of environments and span the entire week is imperative.

STRENGTHS AND LIMITATIONS

This dissertation is not without limitations. Mainly, the data for Chapters 1 and 2 came from a small, pilot intervention and it is unclear how results may generalize to other populations. In Chapter 3, the sample size for the focus groups were small, a decision that was purposeful to maintain the ability to interact amongst participants; however, the smaller size may make establishing implications for the broader population more challenging. Additionally, since the time when we conducted the focus groups, new features on the devices have been developed (e.g., sleeker wristbands, Bluetooth enabled constant synching) and it is unclear how participants may have responded to these updated elements.

In spite of these limitations, the dissertation has several strengths that should be noted. The pilot the data for Chapters 1 and 2 and the population for Chapter 3 was a highly innovative and effective sedentary behavior intervention. By recruiting working and non-working individuals, the data from that pilot allowed for a more thorough exploration into how sedentary behavior may differ across these groups. Given that the majority of previous interventions have focused primarily on working populations, effective strategies to intervene in non-working adults are needed. Additionally, the pilot was the first study to include a specific focus on increasing sit-to-stand transitions. This novel behavior has potential health implications and should be further explored. Results from this dissertation provide important information about opportunities to improve interventions targeting sit-to-stand transitions and that technology could be an effective strategy. Finally, the use of both qualitative and quantitative methods to explore sedentary behavior in more depth provides an important contribution to the field.

CONCLUSIONS

Given that the population as a whole is sitting more than ever and the known negative health outcomes from prolonged sitting, research on this important behavior is a key public health target. This dissertation provides breadth and depth into the field of sedentary behavior research using a combination of methods to further explore this behavior specifically in an older adult population. Results from this dissertation can be used to push the field forward towards including specific measures for sitting time to understand the entire week, specificity of interventions with a distinct focus on sedentary behavior, and how technology can be used to change behavior. In conclusion, the results from this dissertation have major implications for sedentary behavior research overall.

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