Piloting a Smartphone-Based Sedentary Behavior Reduction Intervention for Adults With Overweight or Obesity: Take a STAND 4 Health

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Dedication

This dissertation is dedicated to the amazing people I am fortunate enough to call friends and family. They say it takes a village to raise a child; I think it also takes a village to graduate a PhD student. I have been surrounded and supported by so many wonderful people over the past five years, and I consider myself truly lucky. A special thank you to my mom, who is my rock, my best friend and my biggest fan. I’m not sure I could have done this without her love, support and willingness to drive to South Carolina at the drop of a hat. Thank you to my husband for the love and encouragement he has provided me during our time together. He has always supported me in my endeavors and has put my dreams before his own. I can’t wait to see what our future holds for us. Lastly, I want to thank my cats Finley and Niklaus for keeping me company during the many hours of writing. Their presence made the whole process a little bit better.
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Abstract

INTRODUCTION: Previous studies have shown a relationship between sedentary behavior as an independent and novel risk factor for high blood pressure. However, most of the evidence comes from cross-sectional and experimental studies, with only a few studies examining whether blood pressure is improved in individuals participating in a behavioral intervention. None of these studies utilized mHealth approaches, which hold potential for behavioral interventions, and none have focused on individuals with hypertension as a part of their target population. Therefore, the purpose of the dissertation was to 1) Examine the efficacy of a smartphone-mediated multi-component sedentary behavior reduction intervention for individuals with overweight or obesity and with or without hypertension, 2) Determine whether a change in sedentary behavior resulted in a change in blood pressure, and 3) Establish the best recruitment sources for the target population, participant engagement and satisfaction with the intervention. METHODS: This study was a two-arm randomized controlled pilot feasibility trial comparing the change in objectively measured average daily percent sedentary behavior and blood pressure from baseline to post intervention between participants randomized to the Take a STAND 4 Health (TAS4H) intervention and an assessment only control. Independent and paired t-tests were used to determine whether there were significant changes between groups and within groups,
respectively. In addition, multiple linear regression models were run to determine whether sedentary behavior was a significant predictor for change in blood pressure variables. **RESULTS:** Thirty-six individuals were randomized and 34 were retained for follow-up assessments. Participants were predominately white, well-educated females with a BMI of $35.4 \pm 6.4$ kg/m$^2$. No significant differences were observed for change in average daily percent sedentary time, systolic blood pressure or diastolic blood pressure between the treatment and control group. Multiple linear regression models failed to find evidence of an association between a change in sedentary behavior and mean change in systolic or diastolic blood pressure. When looking at recruitment, participant engagement and satisfaction with the intervention, most TAS4H participants previously participated in one of the lab’s interventions, were referred by a friend, or saw the intervention on a listserv. Engagement with the intervention was high and over 80% of participants feeling like the intervention was helpful for reducing sedentary time and agreeing that they would recommend the intervention to a friend. **CONCLUSIONS:** The TAS4H intervention was not effective in reducing sedentary behavior, which is likely why there was no relationship between sedentary time and blood pressure seen in this study. However, it was well liked and feedback from participants may help inform future sedentary behavior reduction interventions for this population.
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Chapter 1

Introduction

1.1 Problem Identification

Epidemiological literature provides evidence of a detrimental association between sedentary behavior and health conditions such as cardiovascular disease, cancer, metabolic syndrome, type 2 diabetes, and hypertension. Sedentary behavior, which is classified as any waking activity ≤1.5 METs in a sitting or reclining position, is also associated with a 49-54% increased risk for all-cause and a 90% increased risk for cardiovascular disease mortality. The negative relationship between prolonged sedentary time and health outcomes like body mass index (BMI), waist circumference, heart rate, and HDL cholesterol is one mechanism through which sedentary time is thought to detrimentally impact health. A dose response relationship appears to exist with higher levels of sedentary time associated with negative health outcomes, a relationship that is independent of moderate to vigorous physical activity levels, suggesting that sedentary behavior has important health implications. Given the unfavorable impact sedentary behavior has on health, the prevalence of sedentary time in the United States is alarming. Self-reported assessments of sedentary time estimate individuals are sedentary only 3-4 hours a day, but these assessments are based on leisure time activities such as TV viewing and non-
work computer use rather than the full day.\textsuperscript{18} Recent accelerometer data from a large representative population sample estimated American adults actually spend an average of 8-9 hours, or 54.9\%, of their waking day sedentary.\textsuperscript{18,19} Not surprisingly, the age group with the highest percentage of time spent in sedentary behaviors was adults 60 years or older (8.41-9.28 hours). Mexican American adults were the least sedentary compared to Caucasian and African American adults, and females were significantly more sedentary than males until the age of 60 when the trend reversed.\textsuperscript{18} Other studies have shown evidence for additional sociodemographic characteristics correlated with a greater prevalence of sedentary time including a BMI $\geq$ 35 kg/m\textsuperscript{2}, a chronic disease (diabetes, cardiovascular disease, cancer, or emphysema), and the need of special equipment to walk.\textsuperscript{20} Even though there is some variation between subgroups, high levels of sedentary time is consistent across the population. Since a large proportion of the population spends more than 50\% of the day engaging in harmful levels of sedentary behavior, it is becoming a serious public health issue.

There are two key issues when conducting sedentary behavior research. The first is that until recently, the terms “sedentary” and “physically inactive” have been used interchangeably in the literature. However, recent evidence has shown the two behaviors to be distinctly different.\textsuperscript{21} “Sedentary” describes an individual who engages in high levels of sedentary behavior, while “physically inactive” describes an individual who does not engage in enough physical activity to meet a predetermined guideline. The two behaviors often are paired but are not interchangeable as an individual can be both physically active, meaning they meet the 2008 Physical Activity Guidelines, and
also have high levels of sedentary time, resulting in the classification of sedentary. In an attempt to eliminate the confusion, the Sedentary Behavior Research Network (SBRN) recently published a terminology consensus project to clarify the meaning of terms commonly used in sedentary behavior research. Still, some of the earlier sedentary behavior literature is based on the misclassification, which obscures the associations that can be drawn from this literature.

The other key issue is whether to operationalize sedentary behavior as the total time spent sedentary or to classify time in “bouts”, which is defined as a period of uninterrupted sedentary time. There is evidence to suggest that the total amount of sedentary time is not the only contributing factor; the pattern in which it is accumulated also matters. In a recent study, frequent breaks in sedentary time, which led to shorter bouts of sedentary time, were found to have a beneficial effect on health and were positively associated with cardiometabolic risk factors and all-cause mortality independent of both total sedentary time and exercise time. The mingling of these two conceptualizations of sedentary time can be seen in the majority of existing intervention studies which report the primary outcome as a reduction in total sedentary time, yet the intervention target is the promotion of breaks in sedentary time at predefined intervals to yield this reduction. Therefore, it is unclear whether a reduction in total sedentary time or an increase in breaks of sedentary time results in improved health outcomes.

The increase in sedentary behavior prevalence demands the development of effective sedentary behavior interventions. Until recently, interventions focused on increasing moderate to vigorous physical activity (MVPA) have been used in an attempt
to decrease sedentary behavior. However, evidence from two recent meta-analyses showed that interventions which target physical activity only and do not directly address sedentary behavior are not effective in significantly altering sedentary behavior. However, the few studies that target sedentary behavior directly were effective in significantly decreasing sedentary time, demonstrating that physical activity and sedentary behavior are independent behavioral targets and therefore may require different interventions.

A limited number of behavioral interventions specifically focused on modifying sedentary behavior do exist. The existing interventions are primarily randomized control trials or pre-post designs and were implemented either in the workplace or with older adults. Furthermore, they are mostly multi-component interventions and greatly vary in their use of behavioral targets and strategies. The average duration of interventions was four weeks but ranged from five days to six months. However, while there is evidence that an intervention focused on reducing sedentary behavior can be effective, with nearly three-fourths of interventions resulting in significant decreases in sedentary time there is limited information for high risk populations and how a sedentary behavior intervention might affect cardiometabolic outcomes.

Further, very few of the existing interventions have focused on how decreasing sedentary behavior impacts clinical outcomes. A clinical outcome that has been examined by four interventions is blood pressure, and one showed evidence of a significant association between a decrease in sedentary time and improved blood pressure. While the evidence from interventions is limited, data from experimental
studies strengthen the possible relationship between sedentary behavior and blood pressure by demonstrating that blood pressure can be influenced by manipulating sedentary time,\textsuperscript{7,29} even in individuals with hypertension.\textsuperscript{30} However, the impact of a sedentary behavior intervention on the blood pressure of individuals with hypertension has not been studied. Since individuals with hypertension are at a higher risk for fatal or debilitating events like stroke, heart attack, and kidney disease\textsuperscript{31} a sedentary behavior intervention that improves blood pressure could have important implications for this population.

1.2 Scope of the study

The purpose of the study was to determine the effect of a 4-week, technology-mediated sedentary behavior reduction intervention on the change in objectively measured sedentary behavior as measured by an activPAL accelerometer and blood pressure of overweight or obese adults with and without diagnosed hypertension. The proposed study was a pilot, proof-of-concept controlled trial that randomized participants to either the 1) intervention group, which received the intervention for the four weeks of the study or the 2) control group, which acted as an assessment-only condition. The aims of the study include:

1.2.a: Aim 1: Intervention Primary Outcome

The purpose of Aim 1 was to conduct a pilot, proof-of-concept randomized controlled trial to investigate the change in objectively-measured sedentary behavior (total % sedentary time) following a 4-week technology-mediated behavioral
intervention aimed to reduce sedentary behavior among overweight/obese adults with and without diagnosed hypertension.

I. Hypothesis: Participants randomized to the intervention arm will have a significantly greater decrease in total % sedentary time at 4 weeks as compared to participants randomized to the control arm.

1.2.b. Aim 2: Investigate the change in blood pressure of overweight/obese adults with controlled hypertension following a 4-week technology-mediated sedentary behavior intervention.

I. Hypothesis: Participants randomized to the intervention arm will have a significantly greater decrease in systolic and diastolic blood pressure at 4 weeks as compared to participants randomized to the control arm.

1.2.c. Aim 3: Collect process data relevant to study implementation, including recruitment sources and yields, participant engagement, and participant evaluation of the study.
2.1. Issues with Sedentary Behavior Research

There are several challenges when evaluating the literature on sedentary behavior’s impact on health, with the three most fundamental problematic issues being the inconsistency in its definition, its measurement, and its operationalization. These issues have caused some confusion in what researchers meant when identifying an individual as “sedentary”, whether subjective or objective measures are used, and whether classifying sedentary behavior as total time or the number of prolonged bouts is the best approach. While a recent clarification in the definition has begun to resolve the issue of inconsistency, there is still wide variety in all three matters that require reconciliation.

Before a recent terminology consensus project, there were two commonly utilized definitions of sedentary behavior: intensity or intensity + posture. Most epidemiologic research has used the intensity only definition, which is easier to measure than intensity + posture, but this creates a grey area for behaviors like standing. Previous research has included standing and sometimes sleeping as sedentary behavior in some but not all studies. However, now sedentary behavior’s accepted definition is
“any waking behavior characterized by an energy expenditure of $< 1.5$ METs while in a sitting, reclining or lying posture.” The terminology consensus is a major step towards moving the field forward, but greater efforts are needed to distinguish between individuals who are sedentary and individuals who are physically inactive. These two terms have been used interchangeably in the literature, and even though they often go hand in hand, they are distinctly different behaviors with different physiological effects. This can make drawing conclusions from a literature which confounds the two behaviors difficult since a large proportion of studies claiming that sedentary behavior has significant health risks have used physically inactive participants rather than explicitly sedentary individuals. As previously noted, the difference between sedentary and physically inactive individuals is important to distinguish because individuals can be both active by achieving their 30 minutes of physical activity a day and also sedentary because they spent the remainder of the day in sedentary time. The distinction between the two classifications clarifies what is being measured and what associations can be made from future studies.

Another issue is the variability in how sedentary behavior is measured. As previously mentioned, TV viewing time was historically the most common method of assessing sedentary behavior. When the field moved toward assessment of total sedentary time, self-report assessments, such as questionnaires or recalls, were the most predominately used method. While self-reported methods are low cost and have the ability to assess domain-specific sedentary behavior, their validity is much lower when compared to objective measures like accelerometry. Accelerometry also
provides the ability to capture sedentary behavior patterns\textsuperscript{36} and MVPA levels, but it is expensive, burdensome, lacks an ability to provide domain specific information, and provides a lot of raw data that needs to be processed.\textsuperscript{32} Also, not all accelerometers are the same, with currently only one sensitive to both postural changes and intensity, and thus appropriate for quantifying sedentary behavior. This brings into question the utility of data gathered by accelerometers that only measure intensity rather than both intensity and posture. This complicates the comparison of data from different studies since some use a device that cannot fully and accurately classify sedentary behavior.

The last fundamental issue is the need to clearly define how sedentary behavior should be quantified in the literature. With accelerometry, researchers now have the capability to measure the pattern of sedentary behavior in total time, bouts, breaks, etc. The main outcome of a large proportion of studies to date is total sedentary time, but is total time the only variable that matters and/or the variable that matters most? There is evidence that breaks in sedentary time have positive effects on metabolic risk,\textsuperscript{37} independent of total sedentary time and/or physical activity level.\textsuperscript{22} However, most studies report findings in total time, even though the goal of the most of the interventions reported to date is to interrupt prolonged periods of sitting. While breaking up sedentary bouts may result in the intended effect of reducing total sedentary time, the interruptions in sedentary behavior may have positive effects independent of reductions in total sedentary time. Until there is evidence that one or the other, or both, quantifications are important with respect to health, the most beneficial approach for studies focused on sedentary behavior’s impact on health may
be to evaluate outcomes according to both variables to help build the literature, compare results across studies, and illuminate which aspects are critical to public health.

2.2. A review of the epidemiological evidence

2.2.a. Television Viewing Time and Health

Historically the association between sedentary behavior and health outcomes has been based predominately on studies of television viewing time and health.35,38 This has led to a large proportion of the evidence of the association between sedentary time and cardiometabolic risk factors to be based solely on this measure.39 Given the high prevalence of TV viewing, with an average of 4 hours per day, and its popularity as the most common leisure time sedentary activity,40 focusing research on this sedentary pursuit was not unjustified and ignoring these results would seriously diminish important research providing the foundation of literature base establishing the negative health impacts of sedentary behavior. Therefore, the research on TV viewing time and health, and the limitations of this literature, will be examined to determine what conclusions can be made from this literature base and how it might be applied to considerations about total sedentary time and health.

There is evidence from cross sectional and longitudinal studies of an association between TV viewing time and a greater risk of obesity.41 Results from a study by Hu et al. found that each two hour per day increase in TV watching time was associated with a 23% increase in obesity,42 while another found that those watching 4 or more hours per day were four times more likely to be overweight compared to those watching less than one hour of TV.39 A similar dose response relationship is seen for both men and women.
when evaluated separately,\textsuperscript{43,44} as well as for male health professionals.\textsuperscript{45} Overall, there appears to be a consistent dose response relationship with greater levels of TV viewing time associated with a higher risk of obesity.

There is also evidence for an association between TV viewing and other outcomes. Following obesity, the two most consistent associations are between TV viewing and risk for mortality and type 2 diabetes. The trend for mortality is similar for obesity in that an increase in one hour of TV viewing time was associated with a significantly increased risk of all-cause and cardiovascular mortality,\textsuperscript{46} with the greatest risk for those who watched higher amounts per day.\textsuperscript{47,48} There is also a significant association between higher TV viewing time and risk of type 2 diabetes,\textsuperscript{14,42,48,49} with relative risks ranging from 1.2 - 2.4 among those who spend more time viewing TV.\textsuperscript{1,42,48,49} Time spent watching TV has also been associated with other clinical outcomes such as 2-hour plasma glucose,\textsuperscript{50,51} insulin,\textsuperscript{52} blood pressure,\textsuperscript{51} waist circumference,\textsuperscript{51} cholesterol,\textsuperscript{36,53} and triglycerides,\textsuperscript{51} but these associations are weaker, less consistent, and often attenuated when controlled for possible confounders.

Although the associations between TV viewing time and health outcomes are intriguing, they may not accurately represent the relationship between sedentary behavior and health. There is evidence that TV time is positively correlated with other sedentary behaviors in women,\textsuperscript{38} but it is only portion of the time an individual spends sedentary. The use of improved self-report questionnaires and accelerometers has widened sedentary behavior’s scope beyond only television viewing time to include other leisure time activities and domains. This scope expansion has fueled discussion
about what the real health impact of sedentary behavior is and whether it is sedentary behavior or behaviors that occur during television watching time that negatively impact health.54

2.2.b. Total Sedentary Time

The expansion of the impact of sedentary behavior beyond TV viewing alone to all sedentary activities requires a reexamination of the relationship between sedentary behavior and health outcomes, specifically cardiovascular risk factors. One study found TV time is a good proxy for total sedentary time, but others studies have found conflicting results.13,55,56 A critique of the new literature with an expanded focus on total sedentary time is needed to try and answer these critical questions.

2.2.b.1. Sedentary Behavior and Mortality

Similar to TV viewing data, recent epidemiological evidence has shown a negative relationship between total sedentary behavior and all-cause mortality1,12,57 and cardiovascular disease mortality.1,57,58 Since cardiovascular disease, which includes diseases such as heart disease and stroke, is the number one cause of death globally,59 with approximately 750,000 deaths in the United States from heart disease and stroke alone60 it is a major public health concern. The relationship between sedentary behavior and cardiovascular morbidity and mortality could be through sedentary behavior’s negative influence on cardiovascular risk factors like obesity, high cholesterol, insulin resistance, metabolic diseases, and high blood pressure. A possible approach to decreasing an individual’s risk of cardiovascular morbidity and/or mortality is by influencing one of these risk factors by manipulating sedentary behavior. Evaluating the
literature by risk factor may help indicate which risk factors have the strongest association with sedentary behavior and are the most probable outcomes to be influenced by a sedentary behavior intervention.

2.2.b.2. Sedentary Behavior and Obesity

When obesity is discussed as a risk factor for cardiovascular disease, it’s often in relation to its effect on cardiometabolic outcomes like blood sugar, hypertension, and hypercholesterolemia.\textsuperscript{61} However, there is evidence to support obesity being an independent risk factor for cardiovascular disease in both men and women. This is demonstrated by the higher rates of cardiovascular events over the lifetime of obese individuals, even without metabolic abnormalities or comorbid conditions.\textsuperscript{62-64} To better understand the association between sedentary behavior and obesity, data are often examined by both body weight and waist circumference. The distinction has important health implications since a larger waist circumference indicates abdominal adiposity, which has additional health risks independent of a high body weight.\textsuperscript{65,66} Several cross-sectional studies have shown a dose response relationship between greater sedentary time and both weight gain\textsuperscript{42,67-69} and increased waist circumference\textsuperscript{8,17,36,70} independent of physical activity levels.\textsuperscript{8,17,36,42,67,68,70} An inverse relationship between breaks in sedentary time and WC\textsuperscript{17,22,70,71} can also be seen, providing evidence for the independent effect of breaks in sedentary time on cardiometabolic health.

While evidence appears to indicate a significant association between obesity and sedentary behavior, most data are from cross-sectional studies, making it difficult to establish directionality between BMI and sedentary behavior. Obesity, low rates of
physical activity, and high rates of sedentary behavior often co-exist in the same individual, but this does not implicate sedentary behavior as an independent risk factor for obesity. This has sparked discussion on the bidirectional association, which has been speculated in cross sectional studies and explored in two longitudinal studies. These studies, which include subjective and objective measures of sedentary behavior and BMI, both conclude that obesity is a determinant of sedentary behavior rather than a result.

2.2.b.3. Sedentary Behavior and Cholesterol

Hypercholesterolemia (a high total cholesterol, high low-density lipoprotein (LDL) cholesterol, and/or low high-density lipoprotein (HDL) cholesterol) is considered another risk factor for cardiovascular disease. There is little evidence for a relationship between sedentary behavior and either total cholesterol or LDL cholesterol, but four studies have shown a significant association between HDL cholesterol and sedentary behavior, even after controlling for MVPA or both MVPA and BMI. One study found conflicting results with the association attenuated when data were controlled for waist circumference, demonstrating that how data are controlled for possible confounders may influence the association.

2.2.b.4. Sedentary Behavior and Metabolic Diseases

A large proportion of the total sedentary time literature is focused on the relationship between sedentary behavior and metabolic parameters such as insulin, triglycerides, and blood glucose. This could be due to the high prevalence of metabolic diseases, such as metabolic syndrome (MetS) and type 2 diabetes (T2D), or it could be
the direct relationship between sedentary behavior and insulin function, which will be discussed further in a future chapter. Since insulin dysfunction is a key element in the development of metabolic disorders like MetS\textsuperscript{77} and T2D,\textsuperscript{78} the relationship between insulin levels and total sedentary time could have important implications for metabolic disease research and cardiovascular disease prevention.

There is a mix of evidence for the association between sedentary behavior and insulin, blood glucose, and triglycerides levels. Cross sectional studies indicate a negative association between total sedentary time and insulin levels,\textsuperscript{17,76,79,80} but similar to previously mentioned outcomes, this relationship is sometimes attenuated when controlling for possible confounders.\textsuperscript{76,79} Data from longitudinal studies are more mixed, but a study by Barone Gibbs et al.\textsuperscript{80} was unique in that it included both cross sectional and longitudinal results. Data from this study showed a significant cross sectional association between total but no relationship with 5-year metabolic outcomes.\textsuperscript{80} This conflicts with other prospective studies of similar duration which have found that a higher amount of sedentary time predicted a higher level of fasting insulin, even after adjustment for confounders.\textsuperscript{81,82} Sedentary behavior has also been shown to be significantly associated with both blood glucose and triglyceride levels. Some studies have found a significant detrimental association with 2-hour plasma glucose, even after adjustment for MVPA and BMI,\textsuperscript{71} while others have found no association\textsuperscript{83} or the relationship was attenuated after controlling for confounders.\textsuperscript{80} A similar trend is seen with triglycerides, with associations demonstrated in both a systematic review\textsuperscript{5} and
individual studies\textsuperscript{17,36,71,84} between total sedentary time and elevated triglycerides, even after controlling for confounders.\textsuperscript{17,36}

MetS and T2D are prevalent metabolic disorders that are the focus of several sedentary behavior studies. Determining the influence of sedentary behavior on metabolic profile could have important implications for this population since individuals with T2D tend to spend significantly greater time engaged in sedentary behavior.\textsuperscript{73}

Cross-sectionally, there is a consistent dose-response relationship between higher levels of total sedentary time and an increased risk for MetS,\textsuperscript{3,4,8,85-87} even after adjustment for possible confounders such as BMI and MVPA.\textsuperscript{3,8,85,88} The trend is similar for T2D,\textsuperscript{8,80,86} with 15-22\% higher odds of diabetes per 1 hour of sedentary time\textsuperscript{8,86} and a higher level of sedentary time (\textgreater{}10 hours/day) associated with greater odds of having/developing diabetes (OR\textsuperscript{8}= 3.8) when compared to a lower level of sedentary time(\textless{} 6 hours/day).\textsuperscript{80}

For MetS, the pattern in which sedentary behavior was accumulated also appeared to influence risk, with fewer breaks\textsuperscript{3} and prolonged bouts\textsuperscript{88} associated with an increased risk of MetS. Only one study by Barone Gibbs et. al.\textsuperscript{80} has looked prospectively at the impact sedentary behavior has on either disease and in this study, there was no evidence of a significant relationship between total sedentary time and T2D risk.

2.2.b.5. Sedentary Behavior and Hypertension

High blood pressure, or hypertension, is the last cardiovascular risk factor that will be examined and is the focus of this study. The relationship between total sedentary time and high blood pressure, especially in high risk populations, is not well understood, likely because of the paucity of studies.\textsuperscript{89} The existing evidence is predominately from
cross sectional\textsuperscript{7,8,90-92} studies, with only one longitudinal\textsuperscript{6} and three experimental\textsuperscript{29,30,93} studies that evaluate this relationship in adults. Cross sectional studies have shown a positive relationship between sedentary behavior and both systolic and diastolic blood pressure.\textsuperscript{7,8,90-92} This relationship has been evaluated in different ways, with one study looking at blood pressure in different parts of the body and others looking at the effect of sedentary behavior accumulation on blood pressure. A study by Gerage et al. found a significant association between sedentary time, brachial systolic and diastolic blood pressure, and central systolic and diastolic blood pressure.\textsuperscript{7} Another study by Carson et al. found that total sedentary time was associated with diastolic blood pressure and breaks in sedentary time were associated with both systolic and diastolic pressure.\textsuperscript{92} Other studies have looked at the volume of sedentary behavior and found a 14\% increased risk for elevated blood pressure\textsuperscript{8} and significantly higher blood pressure\textsuperscript{90} with higher levels of sedentary time.

When looking at other study designs, the single longitudinal study found that interactive sedentary activities such as driving and computer use were associated with hypertension risk but activities that were less interactive, such as television viewing, has no association.\textsuperscript{6} However, the strongest evidence for the relationship between sedentary behavior and blood pressure results from the experimental research which has looked at how total sedentary time\textsuperscript{93} and breaks in sedentary time\textsuperscript{29,30} affect blood pressure. One study by Pallida et al. detected a significant increase in both systolic and diastolic blood pressure after only one hour of sedentary time, which was accompanied by alternations in blood flow.\textsuperscript{93} The second study found that breaks of either light or
moderate intensity physical activity for two minutes every twenty minutes were significantly associated with lowered systolic and diastolic blood pressure. Lastly, the study by Barone Gibbs et al. found that increasing an individual’s sit-to-stand transitions to at least every 30 minutes resulted in a small but significant decrease in diastolic blood pressure.

A meta-analysis and systematic review looking at the association between sedentary behavior and blood pressure was recently published by Lee et. al. Although the authors found no significant associations, they did note that the most significant effects were seen in those with higher blood pressure as compared to those with lower blood pressure, which demonstrates the possible effectiveness of reducing sedentary behavior for individuals with hypertension or an elevated cardiovascular disease risk. Since the review included the self-reported total sedentary time and included studies focused on children, limiting the results to total sedentary time and only those studies with adult populations could present a different picture more similar to the evidence previously presented.

2.2.b.6. Summary of Sedentary Behavior and Health Outcomes

Data suggest there is a dose response relationship between high levels of sedentary time and negative health outcomes, but the strength and consistency vary by outcome. The most consistent associations appear between sedentary behavior and metabolic diseases and hypertension, but the limited evidence precludes making any definitive conclusions. Also, even though most studies used an objective measure of
sedentary time, the mix of measurement types in a limited literature base restricts the conclusions that can be made to only general associations.

2.3. Physiologic Mechanisms Underlying Health Improvements with Reductions in Sedentary Behavior

While the epidemiologic evidence for a detrimental effect of sedentary behavior on health is encouraging, a lot is still unknown about the physiologic mechanisms underlying the negative impact of sedentary behavior. Determining the biological consequences of sedentary behavior is critical since there is accumulating evidence that shows sedentary behavior physiology is distinctly different from physical inactivity physiology\textsuperscript{21} and that sedentary behavior has a direct influence on metabolic and vascular health.\textsuperscript{95} Even though a large portion of this evidence is from either animal models or bed rest (“physical inactivity”) studies, which are not an accurate representation of human sedentary behavior,\textsuperscript{96} they do provide insight to the potential effects of sedentary behavior.\textsuperscript{97} It is hypothesized from these studies that sedentary behavior impacts health through two key mechanisms (Figure 2.1): a decrease in muscle contraction and a changed artery angle in the lower limbs. This section aims to describe what is known about how these mechanisms negatively impact health, as well as how reductions in sedentary time and increases in light physical activity might positively influence health.

The metabolic consequences of sedentary behavior are thought to occur because of a decrease in muscle contractions that follows when activities that require energy expenditure, like standing and light physical activities (i.e. walking), are replaced with
sitting. This decrease in muscle contractions results in three known outcomes: suppression in skeletal muscle lipoprotein lipase (LPL) activity, a reduction in skeletal muscle GLUT4 receptors, and reduced skeletal muscle blood flow. As can be seen in Figure 2.1, these pathways are not discrete, and each contributes to poor metabolic health either through an increase in triglycerides, a decrease in HDL cholesterol levels, or an increase in insulin resistance.

Evidence from both human\textsuperscript{98,99} and animal\textsuperscript{100} models suggests that the detrimental effects of sedentary behavior could partially be due to the significant decreases in LPL activity seen with decreases in muscle contraction.\textsuperscript{101} LPL, which is influenced by both muscle contraction and insulin levels, is an enzyme responsible for the breakdown of triglycerides into free fatty acids.\textsuperscript{21} A decrease in lower limb skeletal muscle contraction\textsuperscript{102} and to some degree an increase in circulating insulin levels results in a reduction of LPL activity, which is associated with an increase in triglycerides and decrease in HDL cholesterol, and therefore increased cardiovascular disease risk.\textsuperscript{21} While exercise and even standing have been shown to increase LPL levels, these increases are not as substantial as the decreases seen with the lack of muscle contraction in sedentary behavior.\textsuperscript{21,103} However, the evidence is from both human and animal models, so this pathway is merely speculated from the existing data.

A reduction in the translocation of skeletal muscle glucose transporters (GLUT4) is also thought to occur with a decrease in skeletal muscle contraction. GLUT-4 glucose transporters are a key determinant of glucose homeostasis and are independently stimulated by both insulin and exercise in skeletal muscle.\textsuperscript{104} Decreases in muscle
contraction results in a lack of exercise stimulated GLUT-4 translocation, which can lead to high levels of glucose in the blood stream. This increase in blood glucose can result in increased insulin levels, decreased insulin sensitivity, and if chronically elevated, insulin resistance. Insulin resistance has important implications for the insulin stimulated transporters since individuals with insulin resistance have to create more insulin in order to have the same glucose lowering effects. The dramatic increase in insulin levels overworks the transporters and can eventually cause them to no longer function, which demonstrates the importance of exercise stimulated transporters, especially among individuals who are insulin resistant. There is evidence that small increases in muscle contraction resulting from standing or light walking can increase GLUT4 concentrations, which indicates that continual or periodic low intensity activities could be beneficial for glucose tolerance and metabolic health of sedentary individuals.

The last pathway that sedentary behavior is thought to impact metabolic health is through a reduction in blood flow. When standing or moving around, working muscles are contracting and therefore require an increase in blood flow to deliver oxygen and glucose to continue working. However, with sedentary behavior, muscles are not contracting and therefore there is a decrease in blood flow as compared to when an individual is standing or moving. The reduction in blood flow results in less insulin being delivered to the skeletal muscle to facilitate glucose transport into the muscle, which results in a decrease in glucose uptake. Similar to the effects seen with a decrease in GLUT4 transporters, the decrease in blood glucose results in an increase in circulating insulin, a decrease in insulin sensitivity, and eventually insulin resistance. Standing
and/or light intensity breaks in sedentary behavior increases blood flow, which would improve insulin delivery to skeletal muscle, increase blood glucose uptake, and ultimately lead to improved metabolic control.

The other mechanism through which sedentary behavior is believed to impact health is through a change in artery angle. By engaging in prolonged sedentary behavior, an individual is changing the angle of the arteries in the lower limbs for a long period of time. The alteration in artery angle results in an increase in hydrostatic pressure, resulting in decreased blood flow. Reduced blood flow not only decreases insulin delivery to the muscles, as previously mentioned, but additionally results in an altered shear stress in the vessels. A combination of the altered shear stress from a decrease in blood flow and a decrease in insulin delivery from the decreased blood flow results in a reduction of nitric oxide bioavailability. Since nitric oxide is a potent vasodilator and insulin resistance impairs this pathway, the decrease in nitric oxide production results in vasoconstriction, which increases oxidative stress, results in endothelial dysfunction, and eventually can lead to hypertension.107,108 By standing up and/or moving an individual is improving blood flow, which can lead to improved insulin delivery and sensitivity, as well as normal shear stress and a healthy endothelial function. The improvements in endothelial function could have important implications for individuals with hypertension since, as is evidenced in this section, a reduction in sedentary behavior through standing and interrupting bouts of sedentary behavior with light physical activity has the possibility of reducing blood pressure and reducing the risk of cardiovascular disease by improving cardiovascular health.
2.4 Sedentary Behavior Prevalence

The introduction of accelerometers has transformed the way the activity spectrum is measured. These devices have allowed research to rely less on self-report measures, which often underestimate sedentary time,\textsuperscript{109} and instead provide an objective measure of the time and pattern in which sedentary time is accumulated. Population level studies, such as the National Health and Nutrition Examination Survey (NHANES), have recently begun utilizing objective measures of physical activity and sedentary behavior. Even though the devices typically utilized in these studies do not include an inclinometer, which distinguishes between sitting and standing, they provide a preliminary look at objectively measured population level sedentary time.

In 2008, a study published by Matthews et al.\textsuperscript{18} provided the first objective look into the amount of time Americans spend sedentary on a population level across age groups, races, and gender. Results from the 2003-2004 NHANES accelerometer data showed that on average, U.S. children and adults spend approximately 55% of the day, or 7.7 hours per day, engaged in sedentary behavior. After breaking the data into subgroups the most sedentary group was older adults aged 70-85 (males: 67.8%, 9.5 hrs./day; women: 66.3%, 9.1 hrs./day).\textsuperscript{18} The objectively-measured data showed that children and adults were significantly more sedentary than previously thought, with individuals engaging in more than twice the hours of self-reported sedentary time and media use time,\textsuperscript{18} demonstrating that objective measurement likely provides a more comprehensive view of sedentary behavior beyond self-reported media use.
The Matthews et al. study helped establish the prevalence of sedentary behavior based on age, gender, and race/ethnicity, but there are limited data on other possible correlates of sedentary behavior among adults. The bulk of the literature focusing on correlates of sedentary behavior is in children and adolescents,\textsuperscript{110-114} and the studies that do exist for adults are based predominately on screen time,\textsuperscript{40,115,116} breast cancer survivors,\textsuperscript{117} or in the workplace settings.\textsuperscript{118-121} Since the literature began with screen time, some studies have examined correlates associated with higher levels of TV viewing. These studies have found that higher rates of television viewing are associated with a lower level of education,\textsuperscript{40,115,116} a higher BMI,\textsuperscript{40,116} living in a rural area,\textsuperscript{115} age,\textsuperscript{40,115} unemployment,\textsuperscript{40,115} and depressive symptoms.\textsuperscript{40} These data are similar to those seen in an objectively-measured sedentary behavior study which found that older age, a BMI of $\geq 35$ kg/m$^2$ and having a chronic disease (diabetes, cardiovascular disease, cancer, and emphysema) were positively associated with higher levels of sedentary behavior.\textsuperscript{20} Finally, unlike the Matthews et al. article, there was mixed or no evidence for a significant difference between race/ethnicity groups.\textsuperscript{40,122}

Knowing the pattern and duration of sedentary time in the three domains of occupation, transportation and recreation is important for identifying possible intervention targets. Behaviors that occur in specific settings may have distinct determinants or specific patterns, such as prolonged sitting for a screen based occupation.\textsuperscript{123} Even though a recent review showed that there is a decrease in activity across all three domains,\textsuperscript{124} the occupation domain has received the most attention, which is reflected by most behavioral and socioecological sedentary behavior
interventions being implemented in the workplace. One reason could be the 83% increase seen in sedentary occupations since 1950. Another is the high prevalence of sedentary behavior during the workday, with data suggesting office workers spend 66%-82% of the workday sedentary. These high rates are concerning since there are data that show workers do not compensate for their sedentary time during work with less sedentary leisure time activities, with similar levels of sitting during the week and weekend. However, office workers are not the only population at elevated risk, and this focus has left a gap in the literature for sedentary behavior interventions centered on the full day and not just time in the workplace.

2.5 A Review of Sedentary Behavior Interventions

Only recently have researchers began to intervene directly and specifically on sedentary behavior. Early work was predicated on the assumption that by intervening directly on physical activity, changes in sedentary behavior would result; however, such approaches have not been effective in significantly altering sedentary behavior. This is evident by the increased physical activity levels but unchanged sedentary behavior levels produced with these interventions. This demonstrates a need for high quality and evidence-based interventions targeted specifically at sedentary behavior. However, since this is a newly emerging research field, there are currently a limited number of sedentary behavior interventions reported in the literature.

A review of the treatment components and outcomes of the few available sedentary behavior interventions would be informative in efforts to design the optimal intervention. To ensure that the interventions evaluated for this review are sedentary
behavior interventions appropriate for the purpose of this study, an inclusion list that specified necessary criteria for consideration in the review was developed. The list included the following criteria: (1) an adult population; (2) a primary outcome of self-reported or objectively-measured sedentary time; (3) a description of the intervention components; (4) a primary behavioral target of decreasing sedentary time (either total time or interrupting bouts of sedentary time); and (5) data on the change in sedentary time. Interventions that were excluded in the review include those that did not have a reduction in sedentary behavior as the primary outcome or those that provided standing desks as an intervention strategy, since such approaches target the environment rather than implementing behavioral strategies. Applying these criteria, 19 distinct sedentary behavior behavioral intervention studies were identified and are reviewed here.

Of the 19 studies included, 11 were randomized control trials (RCT), 6 were pre-post designs, 1 was a quasi-experimental study, and 1 was a within subjects intervention. The target population for interventions was predominately either adults in the workplace or older adults. The remaining studies targeted adults with type 2 diabetes or at high risk of diabetes, overweight or obese adults, or sedentary adults. Sample sizes ranged from 8 to 213 participants, and intervention duration ranged from 5 days to 6 months. Only 8 of the 19 studies clearly defined the theory underlying the intervention approach; theories used include Social Cognitive Theory, Behavioral Choice Theory, Self Determination Theory, or a combination of conceptual models that included
the aforementioned and others such as Dual-Process theory. Even though less than half of interventions described in the literature explicitly identified a theoretical foundation for the treatment approach, most included behavioral strategies that are consistent with multiple theoretical models. Social Cognitive Theory concepts such as self-regulation, which includes the strategies of self-monitoring, goal setting, and problem solving, and reinforcement, which can occur through feedback and counseling, were present in a large proportion of the studies. Therefore, even if the theory was not clearly stated, the conceptual foundations can be inferred. In the quest to develop an effective sedentary behavior intervention, a review of the behavioral strategies incorporated in the existing 19 intervention studies would be informative.

Fourteen of the nineteen studies resulted in statistically significant decreases in sedentary behavior, with a range in results of -2.2% minutes per day to -837.8 minutes per week. Comparing study results is difficult since sedentary behavior outcomes differed considerably in how change in sedentary time was reported, with outcomes reported in total minutes, % of the day, % wear time, or the number of breaks in sedentary bouts. Even though there was variation in the strategies utilized in these sedentary behavior interventions, which can make cross study comparisons difficult, the strategies that are most commonly incorporated into these interventions reflect those utilized in other behavioral interventions for other targets like weight loss, diet, and physical activity. The frequency and application of these strategies in sedentary behavior interventions is reviewed below.
2.5.a A review of intervention strategies

2.5.a.1 Goal Setting

A brief review of the strategies incorporated in these programs shows that including goals in the intervention, by either prescribing them or setting them with participants, was the most prevalent behavioral strategy. Only two\textsuperscript{25,139} of the nineteen published interventions did not use goals in either capacity and instead provided advice or a list of strategies. Goals can lead to behavior change by directing attention towards specific goal-oriented activities, sparking an increase in the intensity with which a person works towards an outcome, and prolonging persistence to achieving a goal.\textsuperscript{154}

The feature that varied the most between study goals was the behavioral target, which included messages aimed to change break frequency, total sedentary time, step number, or a combination of targets. The goals used in the interventions include light physical activity for two minutes every 20 minutes,\textsuperscript{142} a reduction in sedentary time of 96 minutes per day,\textsuperscript{149} or an increase of 15 breaks per day.\textsuperscript{147} Only one study compared the effectiveness of different goals on decreasing sedentary behavior, randomizing participants to goals of “stand every hour” and “walk 100 steps every hour.”\textsuperscript{135} Results showed that the group given instructions to “stand every hour” significantly decreased sedentary behavior while the group given the goal to “walk 100 steps every hour” did not. The “walk 100 steps” group did however increase their daily steps, which provides limited evidence that a variation in behavioral targets can result in different participant behavior and the overall outcome.
2.5.a.2. Action Planning

A strategy used either in conjunction with goal setting or as an independent strategy was action planning. The strategies are similar but differ in that action planning connects intentions and behavior by providing a clear plan of when, where, and how individuals will change a behavior (i.e. I will walk in place during commercials when watching TV).\textsuperscript{155,156} Action planning was included in five studies,\textsuperscript{137,138,145,146,157} often by having participants identify specific strategies that would be effective in limiting their sedentary behavior according to their schedule and lifestyle. Making the plan specific to a participants’ schedule distinguishes this approach from just providing generic strategies for decreasing sedentary behavior, which was used in two studies.\textsuperscript{140,143}

2.5.a.3. Counseling

Counseling was included in ten\textsuperscript{27,28,138,143-148,157} of the reviewed interventions. Most interventions incorporated multiple counseling sessions throughout the intervention, with a range of one to twelve sessions, and counseling was conducted either in person, by phone call, or a combination of both. Also, with the exception of one intervention, all counseling was done individually rather than in groups. For the studies included, no pattern emerged with respect to which frequency or delivery modality of counseling resulted in significant changes in sedentary behavior; however, two-thirds\textsuperscript{143-148,157} of the interventions that utilized counseling had statistically significant decreases in sedentary behavior.
2.5.a.4 Health Education

Providing health education on the risks of excessive sedentary time and the benefits of decreasing it could have important implications for altering sedentary behavior. Even though all of the studies may have used this strategy, thirteen\textsuperscript{25,28,136-139,143-148,157} explicitly described how the information was relayed to participants and nine\textsuperscript{25,137,143-148,157} of these thirteen had significant decreases in sedentary behavior. Information was most often given at the beginning of the intervention and was delivered through written materials, technology, or a facilitator. Sedentary behavior risk information could be instrumental in the initiation of behavior change since sedentary behavior is a newly emerging research field that has not had the prolonged media coverage that other health behaviors such as physical activity or smoking have had. Therefore, individuals may not only be unaware of the extent of their own sedentary behavior, but also what implications this behavior pattern can have on their health. The control group for two studies\textsuperscript{28,136} received health education on the effects of sedentary behavior, which can serve as a proxy for determining the effect of health education as a standalone strategy on sedentary time. In both studies, the control group did not see significant changes in sedentary behavior, which could indicate that knowledge alone is not effective in changing in sedentary behavior. When looking at the six studies that did not include health education,\textsuperscript{27,135,140-142,149} five\textsuperscript{135,140-142,149} were effective in decreasing sedentary behavior, which suggests that knowledge may not be necessary to significantly change sedentary behavior.
2.5.a.5. Feedback

Feedback was another strategy utilized in nine\textsuperscript{27,28,141,144-149} of the nineteen reviewed interventions, seven\textsuperscript{141,144-147,149,158} of which resulted in significant decreases in sedentary behavior. Feedback was delivered through different modalities including a wearable tracking device, computer program, in person meeting, or a mailed document. Most studies that provided feedback offered information on baseline sedentary data to their participants. The frequency with which feedback was given varied based on the modality of feedback delivery, with interventions that did not utilize a device providing one to seven instances of feedback and device-based interventions providing feedback at least once per day. Technology has transformed the process of feedback since it allows quick or immediate feedback and can aid in the personalization or detail of the feedback.\textsuperscript{159} This immediacy and potential for personalization highlight a benefit of incorporating emerging technology in sedentary behavior interventions. However, incorporation of technology-provided feedback does not guarantee significant impact on sedentary behavior since there is currently no technology specifically designed to provide real-time feedback on various sedentary behavior variables. Feedback provided by technologies could also differ not only in frequency but also in content, resulting in a lack of meaningful feedback on sedentary behavior variables. This content difference could be why two of the four studies that utilized devices as a feedback mechanism in a multi-component intervention failed to find meaningful changes in sedentary behavior. When deciding whether to include feedback as a strategy, it is also prudent to consider the cost-benefit analysis of providing feedback since like counseling, feedback provided
by research staff can be resource intensive, and devices that can provide feedback can be expensive.

2.5.a.6 Self-Monitoring

Self-monitoring of sedentary behavior was reported in nine\textsuperscript{27,28,141,143,145-149} of nineteen interventions, with seven\textsuperscript{141,143,145-149} resulting in significant decreases in the target behavior. Self-monitoring is a self-regulatory technique that requires an individual to pay attention to and record the frequency of a specific behavior, which is why it has been a useful strategy for behaviors such as physical activity and diet.\textsuperscript{153} It is important to note that five other studies\textsuperscript{25,135,140,148,157} included a pedometer as a form of self-monitoring, but since pedometers only measure steps and no aspects of sedentary behavior, the inclusion was not classified as self-monitoring of sedentary behavior. The method used to record total sedentary time or breaks sedentary behavior varied across the studies and included a device, a paper log, or a checklist. The advent of new technologies such as phone applications, websites, and wearables has decreased the burden of self-monitoring in other behavioral interventions. However, while there are currently several activity monitors, most focus predominately on measures of physical activity such as moderate to vigorous exercise minutes and steps rather than multiple sedentary behavior measures like total sedentary time, length in bouts, and breaks in bouts. Some consumer wearables like Fitbits are starting to include sedentary behavior components like “stationary time” and breaks in bouts, but the features of these components cannot be altered, which can make their use difficult in a project whose objectives do not align with the device’s targets. Since there are no technologies
designed specifically to alter sedentary behavior, that include modifiable components, or that can provide real-time feedback on multiple sedentary behavior variables, self-monitoring logs and/or checklists may be a better option at this time. However, as previously mentioned, paper and pen monitoring can be burdensome for participants and it may be difficult for an individual to use a log to monitor a behavior that people are not aware they are doing. As a result, unless an intervention also includes a form of prompting, individuals may not be able to accurately report their frequency or patterns of sedentary behavior.

2.5.a.7. Prompting

Prompting, which uses stimuli (prompts) as a cue to action to encourage an individual to perform a behavior, was used in ten \textsuperscript{25,28,135,136,139-142,147,149} of nineteen studies and served as the main intervention component in 6 of them.\textsuperscript{135,136,139,140,142,149} In these six interventions, prompts were delivered through a wearable device, a smartphone, and/or a computer at differing intervals (20 minutes, 30 minutes, 60 minutes, or 120 minutes). The remaining three studies either used daily emails to prompt participants to self-monitor\textsuperscript{25} or were vague in their utilization of the strategy.\textsuperscript{28,141,147} Seven \textsuperscript{25,135,140-142,147,149} of the ten interventions using prompting resulted in statistically significant decreases in sedentary behavior, which provides limited but positive evidence for prompting as an effective component in sedentary behavior interventions. New technologies make it more feasible to include prompting as a behavioral intervention element, provide an opportunity to capitalize on the latest technology, and offer different modalities through which to deliver the prompts.
However, even though these technologies can be an exciting way to facilitate this strategy, participants may become disengaged with the intervention depending on the frequency and/or the modality of the prompts. There is limited evidence from other literatures about the ideal frequency of prompts\textsuperscript{160} but whether these are the same for sedentary behavior is still to be seen.

2.5.a.8. Other Strategies

Other strategies that were included in the reviewed sedentary behavior interventions included problem solving and social support. Problem solving is the process of identifying a barrier or high risk situation and creating, implementing, and evaluating a plan of how to overcome it\textsuperscript{161} Problem solving is similar to action planning in that both include resolving an issue but the timing differs. The experience of a “failure” in behavior change also differs in that problem solving occurs after behavior change intentions failed but action planning occurs prior to attempting the behavior change. The five\textsuperscript{27,143,144,147,157} interventions that included problem solving also included either goal setting or a prescribed goal, which is logical considering the issues that need solving in behavioral interventions are often barriers to achieving the behavior change goal. Therefore, the effectiveness of problem solving without the use of goals is difficult to tease out. However, given four\textsuperscript{143,144,147,157} of the five interventions that utilized problem solving were successful in significantly reducing sedentary behavior, it appears to be a useful strategy as part of multi-component intervention. Another strategy used was fostering social support, which was included in two of the sedentary behavior interventions.\textsuperscript{25,147} In these two studies, social support for decreased sedentariness was
targeted either through a website or through family and friends. Despite both studies resulting in significant decreases in sedentary behavior, which provides evidence for the potency of social support in changing sedentary behavior, the majority of sedentary behavior interventions have not incorporated a distinct focus on social support. Its success in these studies demonstrates its potential as an effective strategy for interventions interested in capitalizing on the support of others for behavior change.

2.5.a.9. Summary of Intervention Literature Review

This review of existing interventions demonstrates that besides the use of goals, there were very few similarities between the studies in the intervention strategies, theoretical framework or intervention duration. Since there is little comparative work of what strategies are effective in these interventions, and they all are principally multi-component interventions, it is difficult to definitively conclude which strategies should or should not be included. The variety in how strategies were implemented (frequency, in person vs technology delivered, etc.) also complicates strategy selection. Hence, it may be beneficial to include a broader range of strategies rather than focus on a few since it is not clear which strategies are the most effective. Intervention duration was varied with a range of 5 days to 6 months, but if you look specifically at those studies that were effective in decreasing sedentary time, the typical intervention duration mean was four weeks long. As this review demonstrates, sedentary behavior research is a newly emerging field with very few interventions, so there is limited evidence of what comprises an effective sedentary behavior intervention. However, as most interventions included theory-based strategies, having a theoretical basis may be associated with
effectiveness. Also, given the average duration of effective interventions was 4 weeks, it may not take a long period of time to initiate changes in sedentary behavior.
Figure 2.1 Physiologic mechanisms of sedentary behavior
Chapter 3

Methodology

3.1 Intervention Design Overview

The purpose of this pilot randomized controlled trial was to evaluate the impact of a 4-week sedentary behavior reduction intervention on objectively measured total % sedentary time. Overweight and obese adults with and without diagnosed hypertension were randomized to one of two groups (Table 3.1): 1) Intervention group, which received the intervention four weeks, OR 2) Control group, which was as an assessment only condition. The primary objective of the intervention was to decrease participants’ baseline total % sedentary. The secondary objectives include determining how decreasing sedentary time impacts standing time, stepping time, and blood pressure.

3.2 Subject Eligibility

To be eligible for participation, participants must have been at least 18 years old and have a BMI between 25 -50 kg/m². Initially, only individuals with controlled hypertension were recruited and randomized. Hypertension was classified in accordance with the 8th Joint National Committee (JNC) for guidelines, controlled hypertension was classified as a resting blood pressure less than 150/90 mmHg for individuals aged 60 or older without major chronic conditions (diabetes, renal disease,
etc.) or less than 140/90 mmHg for individuals 60 years and older with a chronic disease and individuals 30-59.\textsuperscript{162} Participants were included if their resting blood pressure is less than 160/100 mmHg to account for external influences of a new environment.\textsuperscript{163} However, because of difficulties with recruitment, individuals with overweight or obesity that did not have diagnosed hypertension were included in the study. Therefore, the inclusion criterion of having visited a physician within the last 6 months was removed. Other eligibility criteria included owning a smartphone that is accessible throughout the day, living or working within 30 miles of USC, wearing the activPAL for the baseline measurement, and an average self-reported sedentary time of at least 7 hours a day over the past 7 days (as assessed through the Sedentary Behavior Questionnaire (SBQ)).

Exclusion criteria included: the inability to walk without assistance; recent use of psychotropic medications or treatment for psychological issues, with the exception of anxiety and depression; cognitive impairment or dementia; current treatment for cancer or other serious medical conditions such as renal failure; injury or illness that prohibits standing or walking; current smoker; pregnant or gave birth within the last 6 months; did not live or work within 30 miles of USC; currently enrolled in a weight loss, physical activity, or stress management program; a known vacation or a major alteration in their normal schedule in the subsequent 4 months; and unwillingness to wear the accelerometer for 7 days at any assessment period. Participants must have also been willing to be randomized to either immediate or delayed intervention.
3.3 Participant Recruitment

Recruitment utilized a multi-faceted approach. This approach included: 1) tailored emails sent through distribution lists; 2) recruitment materials (flyers) placed in physician offices; and 3) boosted Facebook posts. Given the target population was a clinical population and individuals with hypertension should visit their doctor every 3-6 months, it was believed that using doctors’ offices could be advantageous for recruitment. Interested participants were directed to the study website where they could enroll in the study. Initial screening questions determined likely eligibility by providing a survey based on the primary inclusion and exclusion criteria and the SBQ. Likely eligible participants were phone screened with a more detailed assessment of eligibility and were offered the opportunity to ask questions. Those who continued to be eligible were invited to an orientation session where study participation was reviewed in greater detail and informed consent was obtained. If still interested, participants scheduled a baseline visit.

Participants were recruited from Columbia, SC, which according to the 2013 South Carolina Department of Health, had approximately 305,800 adults. Recent data estimated that 44.1% of these residents have diagnosed hypertension, resulting in approximately 134,860 adults. Data also indicated that 69% of Richland county residents have overweight or obesity, and since hypertension and being overweight or obese often occur together, it is likely these adults with hypertension were also overweight or obese and therefore fell into our primary inclusion criteria. Given the higher prevalence
of hypertension in minorities, we expected the sample to have a higher percentage of minorities and therefore more closely reflect the hypertension patient population.

3.4 Randomization

Participants were randomly assigned to either the intervention or control group after wearing the activPAL accelerometer for 7 days and completing baseline measurements at the orientation session. A 1:1 random allocation sequence generated by an online sequence generator was utilized for randomization.

3.5 Outcome Measures

A full list of measures and their assessment time points can be found in Table 3.2.

3.5.a Primary Outcome

The primary outcome was change in average daily percent sedentary time, which was assessed using the activPAL device. Participants were asked to wear the accelerometer on their right thigh for 7 consecutive days for 24 hours per day at baseline and four weeks. Also, since the device cannot distinguish between sleep and awake time, participants were provided with a log to record sleep times and other removal times. The activPAL is considered the gold standard for sedentary behavior measurement and has been used in several previous sedentary behavior interventions and has been validated to assess sedentary time. In order for a participant’s data to be considered valid, he or she must have had at least four days of data with at least 10 hours of waking wear time per day. Total % sedentary time was used to account for any variability in monitor wear time.
3.5.b Secondary Outcomes

3.5.b.1 Sedentary time

A bout is defined as “a period of uninterrupted sedentary time” but currently there are no guidelines that define the duration at which sedentary time becomes harmful to health. However, there is some preliminary evidence to show bouts at least 30 minutes in duration have additional negative metabolic health effects. Therefore, for the purposes of this study, a bout was defined as a 30 minute period of uninterrupted sedentary time. Other variables besides total sedentary time that were calculated include the number of 30 minute bouts per day, the total time spent in sedentary bouts longer than 30 minutes, and the number of sit-to-stand transitions. A sit-to-stand transition (i.e. a break) is classified when the participant moves from a sedentary state to an active state.

The SBQ was used as the self-report measure of sedentary time; this measure has been shown to be reliable and valid for overweight adults. We adapted the SBQ so that contemporary examples of sedentary activities are included. For example, tablets will be included as an example along with desktop computers in items identifying use of electronics; these adaptations will preserve the structure of the original questions but will expand the examples to be more comprehensive for current sedentary activities. Obtaining self-reported sedentary behavior provides details about context and situational variation in sedentary patterns which will be useful in identifying intervention targets. Both subjective and objective measures of sedentary behavior were included to provide maximal insights into the contexts, situations and patterns of
sedentary behavior. Further, including both types of measures allows comparison across the range of previous studies, some of which used only subjective and others employ just objective measures.

3.5.b.2 Sociodemographic variables

To assess demographic characteristics, participants completed a baseline survey that included the following variables: age, race, ethnicity, sex, and education. Participants also completed the PAR-Q questionnaire at baseline, which included questions about health history. All medications were assessed at baseline, but blood pressure medication was also assessed at 4 weeks.

3.5.b.3 Physical Activity

Physical activity was assessed using the activPAL and International Physical Activity Questionnaire (IPAQ). The IPAQ is a valid and reliable questionnaire used to estimate both a participants total MET minutes per week and physical activity level (low, moderate, and high). Objectively measured physical activity outcomes that were assessed include total MET minutes per week, time spent standing and time spent sitting.

3.5.b.4 Blood Pressure

There is evidence from previous studies that reducing sedentary behavior may significantly improve blood pressure. Therefore, blood pressure was collected by trained research staff at baseline and 4 weeks to determine the impact of the intervention on blood pressure. Measurements were taken using an automatic blood pressure machine (Omron, HEM 907X Digital Blood Pressure Monitor) and according to
the JNC-8 guidelines.\textsuperscript{162} Participants sat for 5 minutes with their legs uncrossed and blood pressure was taken twice with 60 seconds between measurements then averaged for the final value. If a participant’s blood pressure was greater than 160/100 mmHg, they were ineligible for the study and were recommended to contact their physician.

3.5.b.5 Anthropometrics

Previous studies have shown that a higher BMI is associated with greater sedentary behavior,\textsuperscript{42,68,69} so to control for this variable in analysis, weight measurements were taken at all assessment periods by trained research staff. Height was taken at baseline to the nearest quarter inch using a stadiometer and converted into meters. Weight was taken on a calibrated scale (Tanita BWB 800, Arlington Heights, IL) twice, each measurement period to the nearest tenth of a kilogram. Participants were measured in light clothing and asked to remove their shoes and any items in their pockets. Body mass index (BMI) was calculated using the formula $\text{BMI} = \frac{\text{kilograms}}{\text{meters}^2}$ and categorized as follows: overweight (25.0-29.9 kg/m\textsuperscript{2}) and obese (> 30 kg/m\textsuperscript{2}).\textsuperscript{168}

3.5.b.6 Post-intervention survey

After finishing the intervention, participants completed a survey that assessed their satisfaction with the intervention and provided an opportunity for suggestions for future iterations of the intervention.

3.6 Intervention Description

The Take a STAND 4 Health intervention was a multi-component, goal directed intervention that used a range of behavioral strategies demonstrated to be effective in
previous sedentary behavior studies. Strategies included in the intervention included goal setting, action planning, counseling, health education, feedback, self-monitoring, and prompting. The primary goal of the intervention was to decrease participants’ total sedentary time by 60 minutes per day by the end of the four-week intervention period by encouraging participants to engage in light physical activity (standing, light walking, swaying, etc.). Since there are currently no established sedentary behavior guidelines and the amount of reduction in sedentary time necessary to result in health benefits is unknown, the intervention goal was selected based off of previous interventions that have used 60 minutes$^{27}$ to 10% of the day$^{157}$ as their intervention goal. The implementation of these strategies to achieve the intervention goal is described below.

Even though Social Cognitive Theory is a popular behavioral theory with constructs that were frequently used in the previously reviewed interventions, it does not focus on behaviors that are performed unconsciously. The Dual Process Theory, which was utilized in one previous effective study,$^{137}$ theorizes that both automatic (non-conscious, unintended) and controlled (conscious, volitional) processes influence behavior. The automatic process can be useful for explaining individuals’ sedentary behavior since unlike physical activity, engagement is often unintentional and habitual.$^{169}$ The automatic nature of sedentary behavior indicates that prompting is likely an effective strategy since it acts as a cue to action that raises awareness about the behavior. Other strategies such as action planning, health education, counseling, feedback, self-monitoring, and intention forming (goal setting) affect the controlled processes that influence behavior.$^{169}$ These conscious processes can influence the
automatic nature of sedentary behavior too not only by making individuals more aware of it, but also by helping to “break” the habit and consciously creating new habits. Strategies targeting both the controlled and automatic processes of behavior were utilized since the intervention aimed to not only reduce sedentary behavior but also increase light physical activity. These strategies were implemented through an introductory session, the study specific website and the text message prompts.

3.6.a Introductory Session

After the 7-day activPAL assessment, participants randomized to the intervention group returned for the introductory intervention session. During this session, participants were provided feedback on all 7 days of their objectively measured physical activity and given insight into their sedentary behavior patterns (i.e. morning vs. evening, weekdays vs. weekends, etc.). This facilitated feedback was provided in the form of a graph, which was designed to be a visualization of a participant’s daily activity patterns. The participant then labeled where the prolonged periods of sedentary time occur (workplace, home, and transport) to help contextualize their sedentary behavior, which not only assisted with the action planning process but will also prevented prompts from being delivered during inopportune times such as car travel or sleep. The interventionist and participant then worked together in the action planning process, which is not only helpful for achieving program goals but also in the creation of new habits. Using the domain labeled graph and an intervention worksheet, participant and interventionist determined the most appropriate strategies for the participant in these specific domains (work, home, etc.) to aide in achieving the 60 minute /day reduction in
sedentary time. For example, a domain specific strategy for work would be to stand while making a call or using a bathroom on a different floor.

3.6.b Study Specific Website

After labeling the graph and completing the intervention worksheet, the interventionist registered the participant in the intervention website. Next, the interventionist described how to create a break and reviewed the information the breaks page contained, which included how many prompts are scheduled for each day, when they are scheduled, and the duration of each break. The interventionist and participant reviewed the participant’s graph and selected prompt points, which were based on periods of time on the graph that indicate uninterrupted sedentary time and therefore an optimal point for a planned prompt. However, these prompts were only recommended, and participants were able to tailor them according to their preferences.

After reviewing the feedback page of the website, the interventionist explained how the text message prompting system works and sent each participant an example prompt. Each prompt included the duration of the break and a link. Once a participant clicked on the link, he or she made a selection of how they chose to respond to the prompt. The options included: 1) Taking my [duration] minute break; 2) Needing to snooze my [duration] minute break for 15 minutes; 3) Choosing to skip my [duration] minute break; or 4) Already standing for my [duration] minute break. Once a response was recorded, unless the participant selects to snooze the prompt, there was no further contact until the next scheduled prompt. At the end of the day, participants were able to see the breaks they were and were not able to complete, which provided insight into
a pattern over time. They were also provided feedback on their total sedentary time reduction that day via text the next morning. An example of this text would be:

“Yesterday you took 5 of your 6 scheduled breaks. This decreased your sitting time by 40 minutes, which is 67% of your 60-minute goal. Try to commit to standing more today.” These data were calculated from the text responses. The program was utilized during the 4-week intervention period and the 1-week assessment period. Access was then revoked.

Participants were also provided weekly feedback on their sedentary time and break patterns through the website. Feedback included a day by day comparison of the reduction in sedentary time by day and the break categorization (i.e. number taken, missed, and snoozed), minutes of sedentary time reduction, and the time of day (morning, afternoon or evening) that a participant took, missed, or snoozed their scheduled breaks.

3.6.c Coaching Calls

Additionally, to address participant concerns and assist with goal attainment, participants received telephone calls during weeks 1 and 3 of the intervention. Coaching calls were conducted by the interventionist, followed a semi-structured format, and lasted for approximately 5-10 minutes. Research staff discussed participants’ progress on the intervention goal, barriers participants experienced in achieving the goal, and strategies to overcome these barriers. If the participant was not contacted on the first try, one more attempt was made at a different time point than the initial call (morning, afternoon, evening).
3.7 Data Analysis and Statistical Considerations

Randomization of participants should result in an even distribution of participant characteristics; however, independent t-tests and chi-square analyses were used to evaluate the integrity of randomization and determine what, if any, differences existed between the two groups at baseline. All variables were examined and if significant differences existed, those variables were included as confounders in the analyses. In addition, chi-square analyses were conducted to determine whether there was differential attrition between conditions. There was not differential attrition, so a complete case analysis was used since this is a feasibility study.

Since the distribution of the data met appropriate statistical assumptions, a paired t-test was utilized to evaluate Aim 1’s primary outcome of a differential change in objectively measured average daily % sedentary time from baseline to 4 weeks between the Intervention and Control group. Aim 2 examined whether systolic and diastolic blood pressure from baseline to 4 weeks differentially changed between the Intervention and Control group and was examined using a similar strategy.

Descriptive analyses were used to explore study implementation parameters as outlined in Aim 3 of the study. Data that were summarized include process data on participant recruitment (number recruited, source of recruitment, duration of recruitment, etc.) to inform future studies. Intervention delivery (number of prompts delivered and number of prompts with a response) were characterized. Also, participant evaluations of the intervention were summarized to determine overall satisfaction and
perceptions of the individual intervention strategies to refine the intervention for future iterations.

Additional analyses of sedentary behavior variables were conducted to explore the alternative ways of operationalizing sedentary behavior, allowing more direct comparisons between previous studies and the current data, as well as informing the future selection of optimal operationalization of sedentary behavior in future studies. Descriptive analysis will be used to assess secondary sedentary outcomes (number of bouts over 30 minutes, the average time spent in bouts, and the number of sit-to-stand transitions) to help describe the sample and provide parameters to compare the outcomes of this study with other studies. For all analyses, SAS version 9.4 was used and an alpha level of 0.05 was used to indicate significant differences between conditions.

3.7.a Statistical Power

Given the limited number of sedentary behavior interventions, there are insufficient data from other studies to calculate the required sample size for this study since it was unclear what effect size the intervention would produce. Therefore, the purpose of this proof-of-concept study was to estimate the effect size of this digital sedentary behavior intervention. Since there is sometimes a range of responses to the intervention (i.e., the intervention target is a 60-min reduction in total sedentary time but the expected average change achieved will likely be less than that), one key goal of this study was to determine the average sedentary time reduction achieved, as well as
the variability in change in sedentary time between participants. This will inform sample size estimates for the full-scale trial to follow.

That said, cursory estimates of the power of the proposed study to see significant difference between groups was conducted. G*power 3.0.10 was used to conduct power analyses to explore the power of a paired t-test with an alpha of .05, a standard deviation of 60, and both varying sample sizes (10, 20, 30, 40, 50, 60) and effect sizes (60, 30). Varying effect sizes were used to determine the power if the intervention does not result in a 60-minute reduction but instead a 30-minute reduction. The results of the power calculations are in Table 3.3.

3.8 Strengths and Limitations

Since hypertension disproportionately affects minorities\textsuperscript{170, 171} we anticipated the sample having a higher proportion of minorities, which would more closely resemble the actual hypertension patient population. The representative and diverse sample would add to the generalizability of the findings. The theoretical framework and strategies used in the study are also strengths since the theory is novel to sedentary behavior interventions, with only one previous study having used it, and the strategies are evidenced based approaches that have been effective in previous sedentary behavior interventions. Lastly, the adaptability of the intervention to a participant’s schedule and preferences is a strength since it provided a choice to the participant in selecting the schedule and was therefore more likely to be integrated in their day to day schedule.
The use of the gold standard objective measure of total sedentary time is another strength of the study. While the study sample is a strength in that it reflects a clinical population, it also limits the generalizability of the findings to overweight or obese adults with controlled hypertension. Although the intervention was tailored to the individual, the success of the intervention is therefore dependent on active engagement from the participant, which includes wearing the accelerometer for the two measurement periods and ensuring the intervention group participants have their smartphone near them, which could lead to a high participant burden. Lastly, the study had a small sample size since this was a proof-of-concept study. However, this study will help inform future intervention development by determining the feasibility of certain intervention components such as tailored prompting and smartphone delivery, as well as what can be altered for future iterations.
Table 3.1 Take a STAND 4 Health Study Design

<table>
<thead>
<tr>
<th>Visit 1</th>
<th>Visit 2</th>
<th>Visit 2</th>
<th>Visit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation Session</td>
<td>Randomization Visit (1 week later)</td>
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<td></td>
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<tr>
<td>Be consented</td>
<td>In-Person Session</td>
<td>1</td>
<td>Return for 4-week measures of blood pressure, weight and waist AND have completed online survey</td>
</tr>
<tr>
<td>Wear the activPAL for the next 7 days</td>
<td>Phone Call</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Complete online survey</td>
<td>Phone Call</td>
<td>3</td>
<td>Receive activPAL to wear for 7 days</td>
</tr>
<tr>
<td>Have in-person measurements of blood pressure, height, weight, waist circumference</td>
<td>Phone Call</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

**RANDOMIZED**

**Immediate Group**

**Delayed Group**

Schedule 4-week assessment

No contact
Table 3.2. Variable list and measurement schedule

<table>
<thead>
<tr>
<th>Variable</th>
<th>Baseline</th>
<th>4-Weeks</th>
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<tr>
<td>Medical History and all medications</td>
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<td></td>
</tr>
<tr>
<td>Blood pressure medication</td>
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<td>X</td>
</tr>
<tr>
<td>activPAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Sedentary Time</td>
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<td>X</td>
</tr>
<tr>
<td>% Standing Time</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>% Stepping Time</td>
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<td>X</td>
</tr>
<tr>
<td>Sleep Log</td>
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<td>X</td>
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<tr>
<td>Self-reported Sedentary Behavior</td>
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<td>X</td>
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<tr>
<td>Self-reported Physical Activity</td>
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</tr>
<tr>
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<td>X</td>
</tr>
<tr>
<td>Weight</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Height</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Post-intervention Survey</td>
<td></td>
<td>X</td>
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</table>
Table 3.3. Power analysis results

<table>
<thead>
<tr>
<th>n</th>
<th>Effect size 30</th>
<th>Effect size 60</th>
<th>SD</th>
<th>Alpha</th>
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<tr>
<td>10</td>
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<td>60</td>
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</table>
Chapter 4

Pilot RCT Smartphone-Mediated Sedentary Behavior Reduction Intervention in Adults with Overweight or Obesity

Larsen C, Pellegrini C, Sarzynski M, Ortaglia A, and West D. To be submitted to American Journal of Preventive Medicine
ABSTRACT

Introduction: Given the emerging evidence linking excessive sedentary behavior and negative health outcomes, sedentary behavior may be a novel behavioral target for improving health. mHealth behavioral interventions may be an effective approach considering the pervasiveness of smartphones in the population. The purpose of this pilot randomized controlled trial was to test the efficacy of a smartphone-mediated multi-component sedentary behavior reduction intervention in reducing objectively measured sedentary time.

Methods: Participants were adults with a BMI between 25-50 kg/m² who had full-day access to a smartphone, a self-reported daily sedentary time of at least 7 hours and were willing to be randomized to either the treatment or control group. The 4-week intervention included prompting text messages, a website that provided feedback of self-reported sedentary time reduction, and two coaching phone calls. The primary outcome was a change in average daily percent sedentary time, which was measured using an activPAL inclinometer. Secondary outcomes included percent time standing and stepping, the number of sit-to-stand transitions, and self-reported sedentary time and physical activity. Engagement and treatment satisfaction data were also collected. Paired and independent t-tests were used to evaluate whether there were significant differences within and between groups.

Results: Thirty-six individuals were randomized and 34 were retained for follow-up. Participants were predominately white females with obesity, with no observed differences between groups. There were also no observed significant differences in
percent sedentary time between treatment and control. Engagement with study components was high during the intervention but had no correlation to change in sedentary time.

**Conclusions:** Even though the intervention was well liked, it was not effective in reducing sedentary behavior among adults with overweight or obesity. Future studies should explore which intervention components are effective in reducing sedentary time.

**Trial Registration:** [www.clinicaltrials.gov](http://www.clinicaltrials.gov) NCT03698903

**INTRODUCTION**

Excessive sedentary behavior is an independent risk factor for poor health outcomes such as cardiovascular disease,\(^1^,^2\) type 2 diabetes,\(^3\) diminished physical function\(^4^,^5\) and all-cause mortality.\(^6^\,^7\) The average American spends over half of their day engaged in sedentary behavior.\(^9\) Certain subpopulations, such as individuals with overweight or obesity, are more likely to engage in high levels of sedentary behavior.\(^10\)\(^11^,^12\) Considering adults with overweight or obesity are already at a high risk for chronic conditions\(^13\) and low levels of physical activity,\(^14\) sedentary behavior reduction may be a novel behavioral target for improving health outcomes among these individuals.\(^15\) Previous interventions have been successful in producing significant reductions in sedentary time\(^16^\,^18\) by utilizing a multifaceted approach. Most studies include behavioral strategies such as goal setting, feedback and prompting through technologies such as computer applications, websites and wearables. However, these technology-based approaches can have drawbacks, such as being limited to the workday when using a computer application or relying on the participant to wear and charge a wearable. These
can be major limitations when targeting sedentary behavior, which occurs throughout the day and in many domains.

Mhealth (i.e. mobile health) interventions that use smartphones can overcome these limitations and offer many benefits, such as real-time data collection, scalability, and versatility. They are also ubiquitous in the American population, with nearly 80% of U.S. adults reported owning a smartphone in 2019. Their ability to be used for multi-media interventions (e.g. text messages, phone calls, website, and emails) also make them an appealing medium. Only two previous sedentary behavior reduction interventions have used smartphones as part of a multi-component intervention. Even though each resulted in statistically significant reductions in sedentary time, both used a smartphone application, which needs to be developed for both Apple and Android operating systems. It is unknown whether an intervention utilizing text messages as prompts in a multi-component intervention, which are not operating system specific, can result in sedentary behavior reduction.

The purpose of this pilot study was to examine the effect of a mHealth, multi-component sedentary behavior reduction intervention on the change in sedentary behavior in adults with overweight or obesity.

METHODS

This study was a two-arm randomized controlled pilot feasibility trial comparing change in objectively measured sedentary time between a 4-week multi-component mHealth sedentary behavior reduction intervention (Take a STAND 4 Health) and an
assessment-only control group. The study was conducted in Columbia, SC during 2018-2019 and approved by the University of South Carolina Institutional Review Board.

**Study Sample**

A multi-faceted approach utilizing email distribution lists, online newsletters, online websites, radio advertisements, and boosted Facebook posts was used to recruit participants. In addition, flyers placed in doctor’s offices and presentations to community groups were used. All recruitment materials directed interested individuals to an online screening questionnaire, which determined likely eligibility. Individuals were then contacted by phone to discuss the study further, confirm eligibility, and schedule an orientation session. Eligible individuals included adults with overweight or obesity (body mass index [BMI] > 25 and ≤ 50) who owned a smartphone that was accessible on weekday and weekend days, lived or worked within a sixty minute drive from the clinic, had an average self-reported sedentary time of ≥ 7 hours per day (as assessed by the Sedentary Behavior Questionnaire), were willing to wear the accelerometer for assessment periods, were not participating in another behavioral intervention and were willing to be randomized to either condition. Individuals were initially ineligible if they had not visited their doctor in the past 6 months or were not taking blood pressure medications. However, due to issues in recruitment, these criteria were removed. Informed consent was provided by individuals before engaging in any study procedures.
Randomization and Assessment Procedures

Participants were randomly allocated to either the 4-week Take a STAND 4 Health intervention or the assessment-only control group in a 1:1 ratio using a computer-based random number generator. Even though the interventionist and the participant knew the treatment condition, outcome assessments were conducted by trained staff who were blinded to treatment condition. Condition was revealed to the participant at a randomization visit; if the individual was randomized to the intervention group, the intervention was initiated at the end of the randomization visit. If randomized to the control condition, participants were encouraged to maintain their current behaviors for the duration of the study. All participants were scheduled for a post-assessment visit 4-weeks after their randomization visit.

Smartphone-mediated Multi-Component Sedentary Behavior Reduction Intervention Description

The Take a STAND 4 Health intervention was grounded in Dual Process Theory, which states that sedentary behavior is influenced by both controlled (i.e. conscious) and automatic (i.e. non-conscious) processes. Therefore, to help participants achieve the programmatic goal of a 60-minute reduction of sedentary time per day, key components targeting both processes were included. Controlled processes were targeted with an intention formation worksheet, which provided examples of ways to reduce sedentary time in the home and the workplace, and the self-management strategies of goal setting and problem solving. Prompts, which were designed to remind participants to interrupt their sedentary bouts, were used to target the automatic
processes. The number, duration and timing of the prompts were tailored to the participants’ preferences, schedule, and activity pattern, which was measured using the activPAL. Participants’ were given the ability to modify the schedule at any point in the program; the only stipulation was that the duration still added up to the goal of 60 minutes/day. Prompts were delivered by text and notified the individual that it was time to take their X minute (range: 5-30 minutes) break. After clicking on the link included in the text, participants could select one of four response options: taking the prompt, snoozing the prompt for 15 minutes, skipping the prompt, or are already standing. An example of the prompt can be seen in Figure 4.1.

Participants were also given access to a secure, password-protected study website which provided individualized feedback on their responses to prompts across each day of the intervention and tips on how to alter prompts to more effectively reduce their sedentary time. The intervention also included two problem solving coaching phone calls, which occurred during the first and third week of the intervention. These 5-10-minute phone calls by a certified health educator specialist sought to identify and resolve any barriers the participant felt they encountered when reducing their sedentary time and to offer encouragement. Challenges encountered with the texts and/or the website were also discussed. Participants were also provided with a worksheet that included various strategies for reducing sedentary time.
Measures

*Objectively Measured Sedentary Behavior and Physical Activity*

The primary outcome of the study was percent total sedentary time, which was selected over minutes of sedentary time since percent of the waking day accounts for variability in wear time and waking time. The activPAL device (PAL Technologies Ltd, Glasgow, UK) was used to objectively measure activity, and it was worn for 7 consecutive days at baseline and at 4-week follow-up. The activPAL is a uniaxial inclinometer that measures posture and classifies activity as sitting/lying, standing, or stepping worn affixed to the right thigh.22 It is both valid and reliable and considered the criterion measure for sedentary behavior measurement.22,23 Participants were instructed to wear the waterproofed device for twenty-four hours and given a log to record sleep patterns and monitor removal (if any).

Data were processed using activPAL software. Waking time was identified using reported log information and each assessment period was required to have at least 10 hours per day on a minimum of 4 days to be considered valid.24 Since the intervention goal was framed in terms of reducing daily sedentary time, outcomes assessed for this study were percent waking time engaged in the following behaviors: sedentary, standing and stepping time. Other variables examined include the number of sedentary bouts, the average time spent in sedentary bouts, and the average number of sit-to-stand transitions.
**Self-reported sedentary behavior**

The Sedentary Behavior Questionnaire (SBQ) was used to quantify self-reported sedentary time at baseline and follow-up. The SBQ is a valid and reliable measure\textsuperscript{25} of time spent sedentary across specific domains on both a typical weekday and weekend day; responses range from “15 minutes or less” to “6 or more hours”. For this study, we adapted four of the responses to update the survey and reflect current technologies (e.g. replacing VCR with smartphone or tablet, reading on a tablet or kindle, etc.). A weighted average of daily sedentary time was calculated using the equation 

\[\frac{([\text{weekday} \times 5] + [\text{weekend} \times 2])}{7}\]

and truncated to 1440 minutes (i.e. 24 hours) if the response was greater than 24 hours.\textsuperscript{26}

**Anthropometric data**

Height and weight were obtained by trained staff at baseline, with weight additionally assessed at follow-up. Height and weight were taken without shoes and heavy clothing using a stadiometer and calibrated scale (Tanita BWB 800, Arlington Heights, IL), respectively. Body mass index was then calculated (kg/m\textsuperscript{2}) and categorized into overweight and obesity according to CDC guidelines.\textsuperscript{27}

**Sociodemographics**

Sociodemographic variables were assessed by self-report at baseline and included: age, sex, race, ethnicity, marital status, education, and employment status.

**Intervention Engagement**

Engagement with the intervention components (i.e. text messages and phone calls) was evaluated for individuals randomized to the intervention group. Since
individuals could engage with a text message but not take the break (i.e. choosing to skip or snooze), engagement was separated into the percentage of breaks adhered to (#taken/#scheduled) and overall engagement (#responded to/#scheduled). The percentage of breaks that were snoozed was also examined. In addition, the average duration for the percentage of breaks taken and snoozed was evaluated, as well as the number of completed coaching calls.

*Intervention Evaluation*

Participants randomized to the intervention group evaluated their satisfaction with the program using a 5-point Likert-scale (1=Strongly Agree to 5=Strongly Disagree). Participants also identified the intervention component they felt was most effective and least effective for reducing their sedentary time and provided input on their recommendations for the design of an “ideal” sedentary behavior reduction intervention.

*Statistical Analysis*

Descriptive statistics were used to characterize the sample and examine both engagement and treatment satisfaction data. Independent t-tests and chi-square analyses were used to examine any differences at baseline. Since this was a feasibility study and there was equal attrition between groups, only individuals with both pre and post data were included in the analyses. A paired t-test was used to examine whether there was a change from baseline to 4 weeks within groups and an independent t-test was used to examine differences between groups. Engagement was defined as the
number of prompts answered divided by the number of prompts scheduled. SAS version 9.4 was used for all analyses and an alpha level of 0.05 was set to indicate significance.

RESULTS

Of the 205 individuals who visited the online screener, 117 (57%) completed it. Fifty-four individuals did not meet eligibility criteria, leaving 65 likely eligible individuals. After a brief phone screen, 36 of the 65 likely eligible individuals (55%) met all of the criteria and were randomized. The three most common recruitment sources in this study were listserv advertisements (25%), word of mouth (25%), or an email because of prior participation in a behavioral program (14%). Thirty-four of the 36 randomized individuals were retained for follow up assessments (Figure 4.2). Participants were predominately white (78%) and female (92%) with a mean BMI of $35.4 \pm 6.4 \text{ kg/m}^2$.

There were no observed significant differences between the two groups for either demographics (Table 4.1) or measured variables (Table 4.2) at baseline.

*Primary Outcome Analysis: Change in Objectively Measured Percent Sedentary Time*

All but one participant wore the device for 24 hours for 7 days. Average waking time did not significantly differ between baseline and 4 weeks, with averages of 15.8 $\pm$ 0.9 hours/day and 15.7 $\pm$ 1.1 hours/day, respectively. The average percent sedentary time for all participants was 65.2 $\pm$ 9.6% of participants’ waking day at baseline and 64.0 $\pm$ 10.8% of participants’ day at 4-weeks. No significant changes in percent sedentary time were seen for the intervention group (-0.121 $\pm$ 6.5%; p=0.940), the control group (-2.3 $\pm$ 7.6%; p=0.229), or between groups (p=0.376) (Table 4.2). In addition, for
participants in the treatment group who reduced their sedentary time (n=8), reductions ranged from -1.1% to 14.2%.

Secondary Outcomes Analyses

Similar to change in percent sedentary time, there were no significant differences detected within groups or between groups for change in percent standing time, percent stepping time, number of sedentary bouts, or time spent in sedentary bouts (Table 4.2). However, both the intervention and control groups significantly decreased the number of sit-to-stand transitions from baseline to post test (-3.6 ± 6.4, -2.6 ± 4.6, respectively), with no significant difference between groups. The intervention group significantly reduced self-reported sedentary time by 109.3 ± 192.1 minutes.

Intervention Engagement

On average, participants engaged with 79% of scheduled prompts, meaning they selected any one of the four possible responses. Participants responded “I am taking my break” for 75% of the scheduled prompts per day, resulting in a self-reported sedentary time reduction of 46.1 ± 6.8 minutes per day (Table 4.3). Engagement with the prompts was consistent during the 4 weeks (Figure 4.3). During the two scheduled phone calls, which were completed by 94% of participants, individuals were asked what barriers they experienced to reducing their sedentary time. The most common barriers included a busy schedule (i.e. long meetings, unexpected meetings, etc.), forgetting their phone and therefore unable to engage with the prompts, and the lack of a standing desk.
We failed to find evidence of a correlation between objectively measured sedentary time and either the percentage of breaks adhered to ($r=-0.1; p=0.70$) or the percentage of breaks engaged with ($r=-0.12; p=0.64$).

**Intervention Acceptability and Participant Preferences**

Most participants rated the intervention well, with 82% agreeing or strongly agreeing that they would recommend Take a STAND 4 Health to a family member or friend. Participants agreed that the texts were easy to use (88%) and thought they were helpful for reducing their sedentary time (76%). Only half of participants reported reducing their sedentary time outside of the prompts (47%), but most thought the goal of 60 minutes was possible (76%). When asked about the components included in Take a STAND 4 Health, 71% chose prompts as the most effective tool for reducing their sedentary time and 47% chose website feedback as the least effective component.

**DISCUSSION**

Adults with overweight or obesity did not significantly reduce their average daily percent sedentary time after participating in this multi-component intervention. The only statistically significant changes were a decrease in the number of sit-to-stand transitions for both groups and a reduction in the intervention group’s mean self-reported sedentary time. Engagement with the texts and phone calls was high during the intervention, but we failed to find evidence of a significant relationship between engagement and a reduction in sedentary behavior. Lastly, even though the intervention was not effective in reducing sedentary time, it was highly rated by participants.
Prompting is the most common strategy in digital sedentary behavior reduction interventions\textsuperscript{28} and was the most frequently engaged with strategy in this study. The absence of a reduction in sedentary behavior suggests that the personalization of prompting may make the intervention novel, but it may not be the most effective strategy for sedentary behavior reduction. In the two previous smartphone studies, sedentary time was significantly reduced when assessed in real time using the smartphone’s on-board accelerometer\textsuperscript{16} or a paired accelerometer.\textsuperscript{20} Therefore, even though the prompts in this intervention were based on an individual’s objectively measured activity, it may be more effective to prompt individuals based on objectively measured activity measured in real time rather than based on baseline activity since schedules and activity patterns can change from week to week.

Another discrepancy is the difference between the goals used in previous studies and the goal used in this study. In other interventions targeting adults with overweight or obesity, most utilized a goal focused on increasing steps and/or reducing bouts of sedentary time with sit-to-stand transitions. Only two studies focused explicitly on minutes of sedentary time, and these studies had goals of 2 and 3 hour reductions.\textsuperscript{18,29} Therefore, the 60 minute goal could have been too low to see any significant changes. In addition, the absence of a step goal could explain the lack of a significant reduction in sedentary time. The concept of increasing steps to achieve a step goal is currently more salient in today’s society. In addition, many individuals own wearables such as Fitbit or Apple Watches, and these devices offer objective feedback on their physical activity behavior. Therefore, the approach of targeting sedentary behavior reduction but using
strategies that target both sedentary behavior reduction and physical activity promotion may be an effective approach for reducing sedentary time.

The significant decrease in sit-to-stand transitions contrasts other studies where sit-to-stand transitions either increased\textsuperscript{18,30} or had no change.\textsuperscript{31} However, even though the decrease may seem counterintuitive in a sedentary behavior reduction intervention, a similar result was seen in the study by Pellegrini et. al.\textsuperscript{20} The authors hypothesized that the decrease in sit-to-stand transitions was due to participants taking longer sedentary breaks, resulting in longer standing periods and a diminished need for sit-to-stand transitions. Although there were no significant changes in standing or stepping time to support this hypothesis in the current study, a similar phenomenon may have occurred in this study, just on a smaller scale. In addition, the discrepancy between objectively measured and self-reported sedentary time seen here has been seen in similar studies. There is a response bias that can occur with self-report measures, and since individuals in the intervention group had just participated in the intervention, they likely felt like they reduced their sedentary time, even though objective measures said otherwise.

Overall, three-fourths of participants felt like the intervention was helpful in reducing their sedentary time, with prompts chosen as the most effective intervention component. However, even though participants responded to approximately 75\% of texts, we failed to find evidence of a significant relationship between engagement and a participant’s change in sedentary behavior. One possible explanation could be the lack of accountability during the intervention since the breaks were self-reported rather than
objectively measured. There is no way of knowing whether participants truly participated in the prompts or just reported that they did. Employing a strategy that utilized objective measures could increase that accountability and consequently result in the desired behavior change.

**Strengths and limitations**

Although not effective in reducing sedentary behavior, this study included an innovative intervention that was tailored to participants’ preferences and activity patterns. This personalized approach likely resulted in the high compliance and engagement seen in this study. Another strength was the use of the gold standard activPAL inclinometer in combination with a subjective measure of sedentary behavior. Lastly, the intervention was delivered through technology in participants’ natural environments and was able to intervene in multiple domains and not just the workplace. However, the study also had several limitations. The sample was small and primarily contained well-educated, white women. The study was also only four weeks long, which may not have been long enough to see a change in sedentary behavior with the approach selected for this intervention. Also, some participants encountered issues with the text message system, which led to missing data for engagement variables.

**CONCLUSION**

Given the detrimental associations between sedentary behavior and health outcomes, effective behavioral interventions are needed to reduce the excessive amount of sedentary time adults engage in. Unfortunately, even though this multi-component behavioral intervention was well liked, it was not effective in reducing
sedentary time. Future studies aiming to reduce the sedentary time of adults with overweight or obesity may benefit by using devices that objectively measure activity for prompting and using approaches individuals are familiar with (i.e. steps) for breaking up sedentary time.
References


Table 4.1 Baseline demographic characteristics of the full sample

<table>
<thead>
<tr>
<th></th>
<th>Total N=36</th>
<th>Treatment N=18</th>
<th>Control N=18</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female (%)</td>
<td>33 (92%)</td>
<td>16 (89%)</td>
<td>17 (94%)</td>
<td>0.8864</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>50.7 ± 13.9</td>
<td>52.7 ± 14.8</td>
<td>48.7 ± 12.9</td>
<td>0.3943</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>35.4 ± 6.4</td>
<td>35.0 ± 5.8</td>
<td>35.7 ± 7.0</td>
<td>0.7643</td>
</tr>
<tr>
<td><strong>BMI Categories</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Overweight</td>
<td>22%</td>
<td>22%</td>
<td>22%</td>
<td>1.00</td>
</tr>
<tr>
<td>% Obese</td>
<td>78%</td>
<td>78%</td>
<td>78%</td>
<td></td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>28 (78%)</td>
<td>13 (72%)</td>
<td>15 (83%)</td>
<td>0.6906</td>
</tr>
<tr>
<td>Non-Hispanic Black or African American</td>
<td>8 (22%)</td>
<td>5 (28%)</td>
<td>3 (17%)</td>
<td></td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bachelor’s Degree</td>
<td>8 (22%)</td>
<td>4 (22%)</td>
<td>4 (22%)</td>
<td>0.9214</td>
</tr>
<tr>
<td>Masters or greater</td>
<td>19 (53%)</td>
<td>10 (56%)</td>
<td>9 (50%)</td>
<td></td>
</tr>
<tr>
<td>Other *</td>
<td>8 (25%)</td>
<td>4 (22%)</td>
<td>5 (28%)</td>
<td></td>
</tr>
<tr>
<td><strong>Marital Status</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married</td>
<td>21 (58%)</td>
<td>12 (67%)</td>
<td>9 (50%)</td>
<td>0.311</td>
</tr>
<tr>
<td>Other b</td>
<td>15 (42%)</td>
<td>6 (33%)</td>
<td>9 (50%)</td>
<td></td>
</tr>
<tr>
<td>Employment</td>
<td>Group 1</td>
<td>Group 2</td>
<td>Group 3</td>
<td>Total</td>
</tr>
<tr>
<td>--------------</td>
<td>---------</td>
<td>---------</td>
<td>---------</td>
<td>--------</td>
</tr>
<tr>
<td>Full time</td>
<td>30 (83%)</td>
<td>13 (72%)</td>
<td>17 (94%)</td>
<td>0.1709</td>
</tr>
<tr>
<td>Part time</td>
<td>2 (6%)</td>
<td>2 (11%)</td>
<td>0 (0%)</td>
<td></td>
</tr>
<tr>
<td>Retired</td>
<td>4 (11%)</td>
<td>3 (17%)</td>
<td>1 (6%)</td>
<td></td>
</tr>
</tbody>
</table>

a. High School, vocational training, or some college

b. Divorced, widowed, separated, never married
Table 4.2 Objectively measured and self-reported sedentary behavior by study group

<table>
<thead>
<tr>
<th></th>
<th>Intervention</th>
<th></th>
<th></th>
<th>Control</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P</td>
<td></td>
<td></td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Avg Minutes/Day</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary Time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minutes/Day</td>
<td>635.7 ± 92.1</td>
<td>624.7 ± 82.2</td>
<td>611.3 ± 94.1</td>
<td>582.1 ± 113.1</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Sedentary Time</td>
<td>67.5 ± 8.3</td>
<td>67.3 ± 7.9</td>
<td>63.0 ± 10.4</td>
<td>60.7 ± 12.5</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Standing Time</td>
<td>23.7 ± 7.8</td>
<td>24.1 ± 7.4</td>
<td>27.0 ± 7.5</td>
<td>29.1 ± 10.8</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Stepping Time</td>
<td>8.8 ± 2.6</td>
<td>8.5 ± 2.4</td>
<td>10.0 ± 4.3</td>
<td>10.3 ± 4.4</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Breaks</td>
<td>48.2 ± 14.7</td>
<td>44.6 ± 12.9</td>
<td></td>
<td>51.0 ± 10.5</td>
<td>48.5 ± 10.5</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of 30-Minute Sedentary</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bouts per Day</td>
<td>6.2 ± 1.3</td>
<td>6.0 ± 0.9</td>
<td>5.6 ± 1.7</td>
<td>5.3 ± 1.9</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minutes in Sedentary</td>
<td>370.5 ± 112.5</td>
<td>363.2 ± 94.0</td>
<td>314.8 ± 103.5</td>
<td>305.6 ± 124.6</td>
<td></td>
</tr>
<tr>
<td>Bouts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-reported Sedentary</td>
<td>642.5 ± 167.7</td>
<td>533.2 ± 186.5</td>
<td></td>
<td>668.2 ± 244.9</td>
<td>620.8 ± 266.5</td>
</tr>
<tr>
<td>Minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*= p<0.05
Table 4.3 Text message engagement data

<table>
<thead>
<tr>
<th></th>
<th>Average Number of:</th>
<th>Duration (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prompts Scheduled/Day</strong></td>
<td>6.7 ± 1.4</td>
<td>62.1 ± 4.3</td>
</tr>
<tr>
<td><strong>Prompts Engaged/Day</strong></td>
<td>5.3 ± 1.7</td>
<td>-</td>
</tr>
<tr>
<td><strong>Prompts Adhered to/Day</strong></td>
<td>5.0 ± 1.6</td>
<td>46.1 ± 8.6</td>
</tr>
</tbody>
</table>
Figure 4.1 Take a STAND 4 Health intervention prompt example
Figure 4.2 CONSORT diagram
Figure 4.3. Participant engagement with prompts during TAS4H
Chapter 5

An Evaluation of Blood Pressure After a Sedentary Behavior Reduction Intervention
Among Individuals with and Without Diagnosed Hypertension

Larsen C, Pellegrini C, Sarzynski M, Ortaglia A, and West D. To be submitted to Journal of Hypertension
ABSTRACT

**Background:** Over 100 million US adults have hypertension. Studies have shown an association between high blood pressure and sedentary behavior and a reduction in blood pressure with a reduction in sedentary time. However, these studies have excluded individuals controlling their blood pressure pharmacologically. Therefore, the purpose of this study was to evaluate the blood pressure response to a reduction in sedentary behavior for individuals with overweight or obesity and with or without hypertension.

**Methods:** Adults with overweight or obesity who had full-day access to their smartphone and a self-reported sedentary time of ≥ 7 hours were eligible to participate. The 4-week multi-component mHealth intervention included prompting text messages, a study website, and 2 coaching phone calls. Primary outcome was change in systolic and diastolic blood pressure from baseline to 4-weeks and secondary outcomes were change in objectively measured and self-reported sedentary time. Paired and independent t-tests were used to examine whether there were significant differences within and between groups. Multiple linear regression was used to evaluate if change in sedentary time was significantly associated with a change in blood pressure.

**Main results:** Thirty-six individuals were randomized and 34 completed post assessments. No significant differences between the intervention and control group were observed for any variables tested. Multiple linear regression models failed to find evidence of an association between change in sedentary behavior and mean change in systolic or diastolic blood pressure.
Principal conclusions: We failed to find evidence of an association between change in sedentary behavior and blood pressure response in this study, which was likely due to the lack of change in sedentary behavior.

MANUSCRIPT

INTRODUCTION

Hypertension affects nearly half of adults in the US population and rates are especially high among individuals with overweight or obesity. A large proportion of adults diagnosed with hypertension have poorly managed blood pressure, with the prevalence of controlled hypertension at only 24%. Excessive sedentary behavior has been independently associated with an increased risk of chronic conditions such as cardiovascular disease, type 2 diabetes and high blood pressure, and comprises over half of the average Americans’ waking day. Therefore, reducing sedentary time may be a novel, low-cost and side-effect free behavioral target for reducing blood pressure, especially for those already on medication.

Replacing sedentary time with walking or standing has been associated with lowered blood pressure, even in individuals with hypertension, as well as improved glucose levels and increased energy expenditure. While the manipulations were laboratory-based and lasted for a short duration (e.g. 8 hours), the results provide promising evidence for a relationship between reducing sedentary time and improved cardiometabolic outcomes. Reductions in sedentary time in individuals with overweight or obesity over periods of 12 weeks have also improved cardiometabolic outcomes, such as significant decreases in waist circumference and blood pressure. However,
these studies were focused on individuals without hypertension or those with hypertension but managed without pharmacotherapy; Individuals taking anti-hypertensive medications have been excluded from studies examining cardiometabolic outcomes following sedentary behavior reduction manipulations. With the substantial number of individuals with hypertension who are prescribed anti-hypertensive medications, it is critical to know whether this population experiences blood pressure benefits from sedentary behavior reduction. The current literature does not offer data to inform the question of whether the same blood pressure improvements are noted among individuals who take anti-hypertensive medications for their diagnosed hypertension as have been observed among their normotensive counterparts.

Therefore, the purpose of this pilot feasibility study was to evaluate whether participating in a 4-week sedentary behavior reduction intervention resulted in changes in the systolic and diastolic blood pressure of adults with overweight or obesity and with or without hypertension controlled pharmacologically when compared to an assessment-only condition. Our hypothesis was that a reduction in sedentary time would be associated with a reduction in systolic and diastolic blood pressure in both those with and without hypertension.

METHODS

This study was a two-arm randomized controlled trial examining the change in objectively measured sedentary behavior on the change in systolic and diastolic blood pressure between individuals participating in a 4-week multi-component sedentary
behavior reduction intervention (Take a STAND 4 Health) versus those assigned to an
assessment-only control group.

Participants

Individuals eligible to participate included adults with overweight or obesity
(body mass index [BMI] ≥ 25 and ≤ 50 kg/m²) who lived or worked within a 60-minute
drive of the clinic, had visited a physician within the past 6 months, owned a
smartphone accessible during week days and weekend days, were able to wear the
activPAL accelerometer for 7 days on two occasions, had an average self-reported
sedentary time of ≥ 7 hours per day (as assessed by the Sedentary Behavior
Questionnaire), and were willing to be randomized to either group. Recruitment was
conducted from August 2018 to July 2019. Eligibility was initially limited to individuals
with controlled hypertension (i.e. taking a stable dose of medication to control their
blood pressure). However, difficulty accruing eligible volunteers within the study
timeline required a revision to the eligibility criteria. Approximately 6 months after
active recruitment began, eligibility criteria were revised, and inclusion criteria were
expanded to include individuals without hypertension.

Recruitment and Screening

Participants were recruited using distribution lists, online newsletters and
websites, radio advertisements, boosted Facebook posts, and flyers in doctor’s offices.
Interested individuals first filled out an online screening questionnaire and if likely
eligible, were phone screened. The next step was an in-person orientation session to
learn more about the study and ask any questions. If interested and eligible, the
participant and researcher reviewed the consent form section by section and individuals then provided informed consented and baseline assessments. This study was approved by the University of South Carolina Institutional Review Board.

Randomization and Intervention Description

Using a computer-based random number generator, participants were randomly allocated in a 1:1 ratio to either the 4-week Take a STAND 4 mHealth intervention or the assessment-only control group. One week following the orientation/baseline assessment visit, participants returned for a randomization visit, at which they were informed of their group assignment. If randomized to the intervention group, the intervention session was initiated; if randomized to the control condition, participants were encouraged to continue their current behaviors. All participants were scheduled for a post-assessment in 4-weeks. Trained staff who were blinded to the treatment condition conducted all outcome assessments.

Measures

Blood pressure

Resting blood pressure and heart rate were measured by trained and research staff blinded to treatment condition at baseline and 4-weeks using a research grade automated blood pressure machine (Omron, HEM 907X Digital Blood Pressure Monitor). To ensure the appropriately sized cuff was used, the participant’s arm was measured before assessment. The individual sat for at least five minutes before two measurements with a sixty second period in between were taken. Both measurements and the average were recorded.
**Sedentary Time**

The activPAL device (PAL Technologies Ltd, Glasgow, UK) was used to objectively assess sedentary behavior at baseline and 4-weeks. The activPAL is a uniaxial device shown to reliably measure sedentary, standing, and stepping time.\(^ {22,23}\) Participants were asked to wear the waterproofed device for 24 hours for 7 days at each time point and to complete a log that included their wake and sleep time, reasons for removing the device, and notes about their experience (e.g. experienced irritation and moved it to the left thigh). Data were processed using activPAL software and were considered valid if they included at least 10 hours per day on a minimum of 4 days.\(^ {24}\) Data were analyzed as average percent sedentary, standing and stepping time to account for between and within participant variations in wear time. Since breaks in sedentary time have been shown to be associated with cardiometabolic health,\(^ {45}\) the daily average number of sit-to-stand transitions were also analyzed.

Self-reported sedentary time was assessed at baseline and follow-up using the Sedentary Behavior Questionnaire (SBQ). The SBQ is a valid and reliable measure\(^ {25}\) of sedentary time across nine domains on both an average weekday and weekend day. In this study, four items on the SBQ were modified to reflect current technologies (e.g. replacing VCR with smartphone or tablet, reading on a tablet or kindle, etc.). A weighted average of daily sedentary time was calculated using the equation \[\frac{(\text{weekday} \times 5) + (\text{weekend} \times 2)}{7}\] and truncated to 1440 minutes (i.e. 24 hours) if the response was greater than 24 hours.\(^ {26}\)
Anthropometric data

To ensure participants met the eligibility criteria of overweight or obese, trained staff obtained participants’ height and weight at baseline and only weight at post assessment. Participants were measured without shoes and in light clothing using a stadiometer and calibrated scale. These data were then used to calculate BMI and classify individuals as overweight or obese according to CDC guidelines. 27

Health History and Sociodemographic Variables

The Physical Activity Readiness Questionnaire (PAR-Q) was used at baseline to assess the prevalence of common chronic conditions (e.g. arthritis, cardiovascular disease, metabolic diseases, etc.). Age, sex, race, ethnicity, marital status, education, and employment status were also assessed at baseline using an online survey developed for the study (REDcap, Nashville, TN). Additionally, the number of medications used to control blood pressure and their names was assessed at both time points to determine whether there were any changes during the study. These medication data were used to verify hypertension status.

Take a STAND 4 Health Intervention

The Take a STAND 4 Health intervention was a 4-week mHealth intervention designed to help participants reduce their daily sedentary time by encouraging multiple breaks throughout the day, with a programmatic goal of a 60-minute total reduction in daily sedentary time. The multi-component mHealth intervention was based on Dual-Process Theory 21 and included strategies that targeted both the automatic and conscious processes of behaviors. Participants’ objectively measured activity patterns
and preferences were used to tailor the text message prompts, which were designed to be reminders for participants to stand up during the day. Prompt frequency and duration were selected by the participant and could range from 2 30-minute prompts to 12 5-minute prompts. The only stipulation was that the prompt duration added up to the at least 60 minutes.

Each prompt let the participant know that it was time to take their break, how long that break was set for (e.g. 5-30 minutes), and a link for them to select. Participants were asked to engage with the intervention text messages by clicking the link and responding whether they were planning to take their break, skip their break, snooze their break, or if they were already standing. The self-reported reduction in sedentary time (i.e. I took my break or was already standing) was then displayed on the study specific website. Participants received graphical feedback on their self-reported sedentary behavior reduction, such as the proportion of breaks taken vs missed each day and the number of minutes they self-reported reducing their sedentary time over the past week. In addition, participants received two coaching phone calls during which the interventionist and participant discussed any barriers or challenges the participant was encountering to reducing their sedentary time. Calls lasted for approximately 5-10 minutes.

**Statistical Analyses**

Descriptive statistics were used to characterize the sample; after assessing normality, independent t-tests and chi-square analyses were used to determine whether there were differences between intervention and control groups at baseline.
Since this was a pilot study, a complete case approach was used for all analyses. Paired t-tests were used to examine whether there were group by time differences in sedentary behavior, blood pressure, and other variables within 4 groups: 1) Intervention-Hypertensive (INT-HYP), 2) Intervention-Non-hypertensive (INT-NON), 3) Control-Hypertensive (CON-HYP), and 4) Control-Non-hypertensive (CON-NON). Independent t-tests were used to test whether the changes in variables differed between treatment and control groups. A one-way ANOVA was used to examine differences in changes between the 4 groups.

In addition, since this was the first study to include individuals taking medication to control their blood pressure, differences in blood pressure response and sedentary behavior between those taking hypertension medication and those not taking hypertension medication were examined using paired t-tests. Independent t-tests were used to examine differences at baseline and whether changes between the two groups were significantly different.

Multiple regression was used to investigate the association between the sedentary behavior variables of change in percent sedentary time and change in sit-to-stand transitions and change in systolic blood pressure or diastolic blood pressure. Possible covariates were selected based on the literature and include baseline systolic/diastolic blood pressure, body mass index (BMI), age, race, hypertension status, change in blood pressure medication, and physical activity at follow-up. Intervention group was not included as a covariate in the model since sedentary time did not significantly differ between the two groups and adding the group variable would add
another beta to a model already limited in power. Therefore, all participants were grouped together for these analyses. Correlation was used to assess the relationship between change in systolic/diastolic blood pressure and these variables. A model including all 7 possible covariates is most conceptually sound, but the small sample size would prohibit the inclusion of so many variables. Therefore, both the full model and a more parsimonious model that included a subset of the two most correlated variables were run. However, none of the parsimonious models were more precise, so only the full models are presented in this paper. SAS version 9.4 was used for all analyses and an alpha level of 0.05 was set to indicate significance.

RESULTS

Over 200 individuals visited the online screener, and 117 (57%) completed the survey. Of these individuals, 65 individuals completed the survey and were eligible to be phone screened. Common reasons individuals were ineligible to participate were having a BMI outside of the study range (n=10), not being on blood pressure medication (n=16; note: this was before the criteria changed), and anticipating a major change in their upcoming schedule lasting longer than one week. Forty individuals were invited for orientation, and 36 were randomized. One participant from each group was lost to follow up, leaving 34 individuals being retained for follow up assessments (Figure 5.1).

Most participants were obese (78%), white (78%) females (92%). In addition, most participants had at least a bachelor’s degree (75%), were married (58%), and were employed full time (83%). When examined by those with diagnosed hypertension and those without diagnosed hypertension in the full sample (n=36), individuals with
hypertension were significantly older (p<0.05) and more likely to self-report a metabolic condition (p<0.05) than those without diagnosed hypertension. Those with diagnosed hypertension were significantly older than those without diagnosed hypertension (p<0.05) in the treatment group (Table 5.1).

*Sedentary Behavior and Blood Pressure*

At baseline, participants spent an average of 65.2 ± 9.6 percent of their day sedentary and had an average of 49.6 ± 12.7 sit-to-stand transitions per day. Average blood pressure at baseline was 116.6 ± 12.4 / 75.4 ± 9.7 mmHg with a resting heart rate of 75.8 ± 14.4 beats per minute. When examining by groups, there was no significant group by time change in average percent sedentary time for either the intervention (-0.121 ± 6.54; p=0.940) or control group (-2.312 ± 7.636; p=0.229). The change in average percent sedentary time was also not significantly different between the two groups (p=0.376). When examining those with diagnosed hypertension and those without hypertension, there were no significant changes in percent sedentary time within each treatment group nor did the difference between the treatment groups differ (data not shown) (Table 5.2). There was also no change for either percent standing time or stepping time. Individuals in the INT-HYP group had a significant reduction in self-reported sedentary time of -189.0 ± 205.2 minutes per day (p=0.025) and individuals in the CON-HYP group had a significant reduction in sit-to-stand transitions (p=0.0026). There were no other differences within or between the four groups for either sedentary behavior variables or blood pressure response variables.
Data were also examined by individuals taking blood pressure medication (n=17) and individuals not on blood pressure medication (n=17). Since some individuals were diagnosed with hypertension but chose to manage it without pharmacotherapy, the proportion is different than hypertensive vs. non-hypertensive. There were no significant differences within or between groups for change in percent sedentary time, systolic blood pressure, diastolic blood pressure, or heart rate (Table 5.3).

*Relationship between Sedentary Behavior Variables and Blood Pressure Response*

The relationships between change in percent sedentary time and change in sit-to-stand transitions and systolic blood pressure and diastolic blood pressure were explored using multiple regression (Table 5.4). In all four models, we failed to find a significant association between either of the sedentary behavior variables of change in percent sedentary time or change in sit-to-stand transitions and change in either systolic blood pressure or change in diastolic blood pressure.

**DISCUSSION**

This pilot study explored whether significant changes in systolic or diastolic blood pressure were observed following a sedentary behavior reduction intervention. A significant change in average percent sedentary time for individuals of differing hypertension status, treatment group, or medication use was not observed after the intervention. Evidence of significant differences in systolic blood pressure, diastolic blood pressure or resting heart rate among those who took blood pressure medication and those who did not was also not detected either pre or post-treatment. Lastly,
neither percent sedentary time nor breaks in sedentary time were associated with change in systolic blood pressure or diastolic blood pressure.

The ineffectiveness of the intervention could explain the lack of change in blood pressure seen in this study. In previous studies examining the effect of a sedentary behavior intervention on sedentary time and cardiometabolic outcomes, reduction in sedentary time ranged from 3.7%\(^{17}\) to 7%.\(^{42}\) Regrettably, the average sedentary behavior reduction was only -0.12% for the intervention group in this study. There was also no observed association between a change in sit-to-stand transitions and change in blood pressure. This is likely due to the significant decrease in the number of sit-to-stand transitions seen in this study. Even though percent standing time did not significantly increase in this study, participants may have engaged in prolonged periods of standing during the study. Increased standing could produce increases in blood pressure since prolonged occupational standing has been linked to a two-fold risk of cardiovascular disease in a recent study\(^{49}\) through the potential mechanisms of blood pooling in the lower limbs, increased hydrostatic venous pressure and enhanced oxidative stress.\(^{50-52}\) Future research determining whether focusing on sit-to-stand transitions rather than a total sedentary time goal influences cardiometabolic outcomes is warranted.

In this study, there were no observed differences in blood pressure between those taking blood pressure medication and those not taking blood pressure medication. Average baseline blood pressure for participants taking blood pressure medication was \(116.6 + 13.2/74.6 + 11.3\) mmHg, suggesting their blood pressure was in
fact controlled. Baseline systolic blood pressure in other studies ranged from $122.6 \pm 7.9$ to $133.8 \pm 7.2$ mmHg in one study\textsuperscript{15} to $132 \pm 9.0$ mmHg in another.\textsuperscript{38} Since we did not see a significant decrease in sedentary time, it is unclear whether reducing sedentary time decreases the blood pressure of individuals taking blood pressure medication. Future studies that effectively reduce sedentary time and include participants both with and without diagnosed hypertension are needed to determine the role medication usage may have in the relationship between sedentary behavior reduction and blood pressure.

Although we did not see the hypothesized relationship between a reduction in sedentary time and reduction in blood pressure, this is the first study to our knowledge that explicitly focuses on the blood pressure response of overweight or obese individuals taking medication to control their blood pressure in a sedentary behavior reduction intervention. In addition, it was one of the first studies to examine the relationship of sedentary behavior change and blood pressure outside of a laboratory. However, this study also had several limitations. The study was only powered to detect a difference in sedentary behavior not secondary outcomes. Also, blood pressure can be easily influenced by a multitude of variables including time of day, diet, and stress. These variables were not strictly controlled in this study, which could have led to the null results seen here. In addition, the demands of the protocol may have added additional stress, so future research examining blood pressure may benefit from including a measure of stress associated with a demanding intervention protocol. We also did not assess whether individuals who were taking medication to control their
blood pressure took their medication the day they were being assessed or the time of
day they took the medication. Blood pressure was additionally often assessed at
different time points during the day to accommodate participant schedules. Also, even
though physical activity interventions have seen reductions in blood pressure in 4
weeks,\textsuperscript{36,37} it is unknown whether a sedentary behavior reduction intervention needs to
be longer than 4-weeks to influence blood pressure. Lastly, while we assessed whether
individuals changed the number of medications taken during the intervention, we did
not assess whether individuals changed their blood pressure medication dosage during
the intervention.

**CONCLUSION**

This study sought to examine the relationship between a change in sedentary
behavior and blood pressure response. However, due to a minimal reduction in
sedentary time, there was no observed relationship between a change in sedentary
behavior and blood pressure in this study. Future sedentary behavior reduction
interventions designed to influence blood pressure may benefit from frequent breaks of
physical activity and controlling for assessing all variables that could influence blood
pressure measurement.
References


6. Gerage AM, Benedetti TR, Farah BQ, et al. Sedentary behavior and light physical activity are associated with brachial and central blood pressure in hypertensive...
2015;10(12):e0146078.https://doi.org/10.1371/journal.pone.0146078


<table>
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<th>Control</th>
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<td></td>
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<td>NORM</td>
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<td>NORM</td>
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<td>N=10</td>
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<td></td>
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<td></td>
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<tr>
<td>Female, n(%)</td>
<td>16 (89)</td>
<td>10 (100)</td>
<td>6 (75)</td>
<td>17 (94)</td>
<td>9 (90)</td>
<td>8 (100)</td>
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<td>Male, n(%)</td>
<td>2 (11)</td>
<td>0</td>
<td>2 (25)</td>
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<td>Age (years)</td>
<td>51.6 ± 14.6</td>
<td>59.7 ± 10.4</td>
<td>43.9 ± 15.3</td>
<td>49.1 ± 13.2</td>
<td>53.5 ± 11.2</td>
<td>42.6 ± 13.0</td>
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<tr>
<td>BMI</td>
<td>35.0 ± 5.8</td>
<td>36.5 ± 6.1</td>
<td>33.2 ± 5.2</td>
<td>35.7 ± 7.0</td>
<td>35.2 ± 6.7</td>
<td>36.3 ± 7.8</td>
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<tr>
<td>BMI Categories n(%)</td>
<td>4 (22)</td>
<td>1 (10)</td>
<td>3 (38)</td>
<td>4 (22)</td>
<td>3 (30)</td>
<td>1 (13)</td>
</tr>
<tr>
<td>% OW</td>
<td>14 (88)</td>
<td>9 (90)</td>
<td>5 (62)</td>
<td>14 (88)</td>
<td>7 (70)</td>
<td>7 (87)</td>
</tr>
<tr>
<td>% OB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Race n(%)</td>
<td>13 (72)</td>
<td>8 (80)</td>
<td>5 (62)</td>
<td>15 (83)</td>
<td>9 (90)</td>
<td>6 (75)</td>
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Table 5.1. Baseline demographic characteristics of the full sample
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<td>White</td>
<td>5 (28)</td>
<td>13 (72)</td>
<td>2 (20)</td>
<td>6 (60)</td>
<td>7 (82)</td>
</tr>
<tr>
<td>Black or AA</td>
<td>3 (17)</td>
<td>7 (82)</td>
<td>1 (13)</td>
<td>0 (0)</td>
<td>8 (80)</td>
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<tr>
<td>CVD Condition n(%)</td>
<td>5 (28)</td>
<td>13 (72)</td>
<td>4 (40)</td>
<td>6 (60)</td>
<td>7 (82)</td>
</tr>
<tr>
<td>Metabolic</td>
<td>4 (22)</td>
<td>14 (78)</td>
<td>4 (40)</td>
<td>6 (60)</td>
<td>8 (100)</td>
</tr>
<tr>
<td>Condition n(%)</td>
<td>4 (22)</td>
<td>14 (78)</td>
<td>4 (40)</td>
<td>6 (60)</td>
<td>8 (100)</td>
</tr>
</tbody>
</table>

Greyed boxes = difference between groups p < 0.05

Footnotes

HYP= Hypertensive

NORM= Normotensive

BMI= Body Mass Index

CVD= Cardiovascular disease
Table 5.2. Objectively measured and self-reported sedentary behavior and physical activity, systolic blood pressure, diastolic blood pressure and heart rate by hypertension status and treatment group

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<th>Intervention</th>
<th>Control</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>4-Week</td>
</tr>
<tr>
<td><strong>% Sed Time</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>67.5 ± 8.3</td>
<td>67.3 ± 7.9</td>
</tr>
<tr>
<td>Hypertensive</td>
<td>67.4 ± 10.5</td>
<td>68.8 ± 9.2</td>
</tr>
<tr>
<td>Non-Hypertensive</td>
<td>67.6 ± 5.8</td>
<td>65.7 ± 6.3</td>
</tr>
<tr>
<td><strong>% Standing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>23.7 ± 7.8</td>
<td>24.1 ± 7.4</td>
</tr>
<tr>
<td>Hypertensive</td>
<td>24.4 ± 10.0</td>
<td>23.3 ± 9.0</td>
</tr>
<tr>
<td>Non-Hypertensive</td>
<td>22.9 ± 5.0</td>
<td>25.0 ± 5.6</td>
</tr>
<tr>
<td><strong>% Stepping</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>8.8 ± 2.6</td>
<td>8.5 ± 2.4</td>
</tr>
<tr>
<td>Hypertensive</td>
<td>8.2 ± 3.1</td>
<td>7.9 ± 2.3</td>
</tr>
<tr>
<td>Non-Hypertensive</td>
<td>9.5 ± 1.8</td>
<td>9.3 ± 2.5</td>
</tr>
<tr>
<td><strong>Sit-to-stand Transitions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All</td>
<td>48.2 ± 14.7</td>
<td>44.6 ± 12.9</td>
</tr>
<tr>
<td>Hypertensive</td>
<td>49.1 ± 19.1</td>
<td>44.2 ± 16.1</td>
</tr>
<tr>
<td>Non-Hypertensive</td>
<td>47.1 ± 8.7</td>
<td>44.9 ± 9.2</td>
</tr>
<tr>
<td></td>
<td>All</td>
<td>Hypertensive</td>
</tr>
<tr>
<td>------------------</td>
<td>-----------</td>
<td>--------------</td>
</tr>
<tr>
<td><strong>Self-Reported</strong></td>
<td>642.5 ± 167.7</td>
<td>495.2 ± 175.3</td>
</tr>
<tr>
<td><strong>Sed Time</strong></td>
<td><strong>533.2 ± 186.5</strong></td>
<td><strong>495.2 ± 175.3</strong></td>
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<tr>
<td><strong>Systolic</strong> (mmHg)</td>
<td>116.2 ± 14.8</td>
<td>120.1 ± 16.3</td>
</tr>
<tr>
<td><strong>Diastolic</strong> (mmHg)</td>
<td>75.5 ± 10.2</td>
<td>73.2 ± 11.9</td>
</tr>
<tr>
<td><strong>Heart Rate</strong> (bpm)</td>
<td>78.1 ± 11.3</td>
<td>78.5 ± 13.5</td>
</tr>
</tbody>
</table>

*p <0.05
Table 5.3. Change in sedentary time and blood pressure response for those taking blood pressure medication vs. those not taking blood pressure medication

<table>
<thead>
<tr>
<th></th>
<th>No Blood Pressure Medication</th>
<th>Blood Pressure Medication</th>
<th>Between groups p-value</th>
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<tbody>
<tr>
<td></td>
<td>N=17</td>
<td>N=17</td>
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</tr>
<tr>
<td>Baseline % Sedentary Time</td>
<td>66.2 ± 9.7</td>
<td>64.2 ± 9.7</td>
<td>0.8232</td>
</tr>
<tr>
<td>Change in % sedentary time</td>
<td>-1.5 ± 5.3</td>
<td>-0.94 ± 8.7</td>
<td></td>
</tr>
<tr>
<td>Change p-value</td>
<td>0.2623</td>
<td>0.6615</td>
<td></td>
</tr>
<tr>
<td>Baseline SBP (mmHg)</td>
<td>116.6 ± 12.0</td>
<td>116.6 ± 13.2</td>
<td>0.8902</td>
</tr>
<tr>
<td>Change in SBP (mmHg)</td>
<td>5.0 ± 12.2</td>
<td>4.4 ± 12.4</td>
<td></td>
</tr>
<tr>
<td>Change p-value</td>
<td>0.1106</td>
<td>0.1630</td>
<td></td>
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<tr>
<td>Baseline DBP (mmHg)</td>
<td>76.1 ± 8.0</td>
<td>74.6 ± 11.3</td>
<td>0.3724</td>
</tr>
<tr>
<td>Change in DBP (mmHg)</td>
<td>3.0 ± 8.3</td>
<td>0.5 ± 7.6</td>
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<tr>
<td>Change p-value</td>
<td>0.1566</td>
<td>0.7772</td>
<td></td>
</tr>
<tr>
<td>Baseline Heart Rate (bpm)</td>
<td>72.9 ± 11.1</td>
<td>78.6 ± 17.0</td>
<td>0.2547</td>
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<tr>
<td>Change in Heart Rate (bpm)</td>
<td>-2.1 ± 8.5</td>
<td>1.5 ± 9.3</td>
<td></td>
</tr>
<tr>
<td>Change p-value</td>
<td>0.3302</td>
<td>0.5225</td>
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Table 5.4. Multiple linear regression results for the association between sedentary behavior variables and blood pressure response

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<th>Systolic Blood Pressure</th>
<th>Diastolic Blood Pressure</th>
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<td>Change in % Sedentary Time</td>
<td>Change in Breaks</td>
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<tr>
<td>R^2</td>
<td>43.2%</td>
<td>43.0%</td>
</tr>
<tr>
<td>Intercept</td>
<td>2.75 (29.4)</td>
<td>7.75 (30.2)</td>
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<tr>
<td>Change in sedentary variable</td>
<td>-0.16 (0.29)</td>
<td>0.16 (0.36)</td>
</tr>
<tr>
<td>Baseline Systolic Blood Pressure (mmHg)</td>
<td>-0.44 (0.16) *</td>
<td>-0.45 (0.16) *</td>
</tr>
<tr>
<td>Body Mass Index (kg/m^2)</td>
<td>0.70 (0.16)</td>
<td>0.74 (0.34) *</td>
</tr>
<tr>
<td>Age (years)</td>
<td>0.31 (0.18)</td>
<td>0.28 (0.18)</td>
</tr>
<tr>
<td>Race</td>
<td>-0.59 (5.1)</td>
<td>-1.78 (5.0)</td>
</tr>
<tr>
<td>Hypertension Status</td>
<td>8.05 (4.4)</td>
<td>7.53 (4.7)</td>
</tr>
<tr>
<td>Change in Medication</td>
<td>7.0 (5.0)</td>
<td>6.83 (5.1)</td>
</tr>
<tr>
<td>Physical Activity at 4 Weeks (% of day)</td>
<td>0.04 (0.55)</td>
<td>0.03 (0.55)</td>
</tr>
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</table>

* Indicates statistical significance.
Figure 5.1. CONSORT diagram
Chapter 6

Discussion

6.1. Study Summary and Implications

Emerging epidemiologic evidence indicates a detrimental relationship between sedentary behavior and cardiometabolic health.\textsuperscript{3,54} However, few studies have examined whether reducing sedentary time can improve cardiometabolic outcomes,\textsuperscript{15,17} and none have specifically focused on individuals taking medication to control their blood pressure. Hypertension affects 33\% of adults aged 40-59 and 63\% of adults over 60.\textsuperscript{55} Since hypertension puts individuals at a higher risk for fatal or debilitating events like a stroke or heart attack,\textsuperscript{56} determining whether a sedentary behavior intervention improves blood pressure could have important implications for this clinical population.

In order to establish whether there is a relationship between a sedentary behavior reduction intervention and an improvement in blood pressure, you first need to develop an evidence-based behavioral intervention. eHealth/mHealth approaches are becoming increasingly popular in behavioral interventions due to the ubiquity and availability of technologies, and a recent systematic review and meta-analysis showed that eHealth/mHealth-enhanced interventions can be effective in reducing sedentary time.\textsuperscript{28} Some mediums, such as smartphones, may be particularly attractive when targeting
clinical population such as individuals with hypertension since 79% of adults 50-64 years old own a smartphone. Therefore, designing an intervention to capitalize on the prevalent technology in this clinical population could be advantageous.

The Take a STAND 4 Health (TAS4H) study was a 4-week pilot randomized controlled trial that 1) tested the intervention’s efficacy in reducing the sedentary time of adults with overweight or obesity and with or without diagnosed hypertension, 2) examined the relationship between a change in sedentary behavior variables and systolic/diastolic blood pressure, and 3) analyzed intervention engagement, recruitment yields, and treatment satisfaction of participants.

Take a STAND 4 Health was a theory-based multi-component intervention that incorporated several key elements, including feedback, prompting, goal setting, action planning and problem solving. These strategies were implemented using an intervention session, during which participants selected strategies they felt were feasible for them to reduce their sedentary time and home and at work; text messages that were delivered daily and acted as prompts for participants to stand; a website that provided graphical feedback on text message responses; and two problem solving phone calls that allowed the participant to discuss any challenges he or she was experiencing to reducing sedentary time.

To test Aim 1, objectively measured average daily percent sedentary time was compared from baseline to 4-weeks for both the intervention and the assessment-only control group. Individuals randomized to the intervention group did not significantly reduce their average daily percent sedentary time after participating in this
smartphone-mediated multi-component intervention. Even though this study took a socio-ecological approach and targeted multiple domains, it is possible that a stronger emphasis on the environmental domain, such as the inclusion of standing desks, is needed to induce greater changes in sedentary time.15 Almost 90% of the sample was employed full or part time, and many expressed frustrations in trying to reduce workplace sedentary behavior. Several individuals also mentioned the social constraints of standing at work, such as getting weird looks when standing in meetings or seminars. The environmental domain may therefore need more emphasis than it was given in this study to enact a significant behavior change.

The primary purpose of Aim 2 was to examine the relationship between a change in sedentary behavior variables and change in systolic and diastolic blood pressure. Since the study included both individuals with and without hypertension, we were able to examine whether there were any significant differences in sedentary behavior and blood pressure variables between groups. There were minimal differences in the change in both sedentary behavior and blood pressure response between treatment and control participants by hypertension status and change in percent sedentary time and change in sit-to-stand transitions were not significant predictors of a change in systolic or diastolic blood pressure. It is unknown whether the absence of a significant relationship between sedentary behavior change and blood pressure change is due to the minimal change in sedentary behavior variables seen in this study or whether standing periodically is not enough of a physiologic stimulus to change blood pressure. In fact, while the change in blood pressure response was not statistically
significant, it appeared that standing for prolonged periods of time may have actually increased blood pressure in those with and without diagnosed hypertension. Therefore, similar to the experimental studies\textsuperscript{37,38} and intervention study examining blood pressure,\textsuperscript{15} studies designed to influence blood pressure may benefit from focusing on frequent sit-to-stand transitions throughout the day or short bouts of non-exercise physical activity (e.g. low intensity daily activities like cleaning or shopping) to see significant decreases in blood pressure.

Aim 3 focused on the recruitment process, intervention engagement, and treatment satisfaction of the TAS4H study. Recruiting individuals with hypertension for a sedentary behavior reduction intervention proved to be much more difficult than expected. This difficulty led to a change in the target population halfway through the study, which will be discussed in more detail in the limitations. Engagement with the intervention was high and three-fourths of participants felt like the intervention was helpful in reducing their sedentary time. Although there are no data for the most effective behavior change technique in digital sedentary behavior reduction interventions, the use of prompts or cues was the most frequently utilized strategy in sedentary behavior interventions a recent systematic review\textsuperscript{28} and was the strategy identified by participants as the most effective intervention component in TAS4H. However, the tailored prompting approach utilized in this study did not appear to influence sedentary behavior, so mHealth interventions using prompts may be more successful utilizing strategies that were effective in other studies, including prompts that were more frequent and informed by objectively measured activity.\textsuperscript{16,20}
6.2. Limitations

This study experienced several limitations and results should therefore be interpreted with these in mind. The TAS4H study initially was focused only on individuals with overweight or obesity taking medication to control their hypertension. However, after using a multi-faceted recruitment approach for over 5 months, only a third of the target sample size was recruited. The hypertension-related criteria were then removed, and the target population was changed to only individuals with overweight or obesity. Therefore, the study’s blood pressure response results cannot be generalized to individuals with controlled hypertension, as originally planned, since the sample was expanded to include individuals without controlled hypertension. In addition, since the sample was homogenous and predominately consisted of white, well-educated females, the generalizability of all study findings are limited to this population.

Since hypertension and obesity disproportionately affect minorities, we anticipated having a sample that mirrored the clinical hypertension patient population. However, the sample garnered in this study was very homogenous and consisted of predominately well-educated, white females. African Americans only constituted 20% of the sample and none of the African American participants were male. It is unclear whether the recruitment methods used were not appropriate for recruiting a diverse sample or whether education level played a role in the interest in sedentary behavior as a health risk. The lack of diversity precluded any comparison of variables between subgroups, such as gender, race or age. Therefore, a more diverse sample is needed to parse out whether certain strategies or approaches work better for some subgroups.
than others, as well as whether certain variables play a role in the effectiveness of sedentary behavior reduction on change in health.

This was a pilot feasibility study to gather data to allow calculation of the required sample size for a full-scale trial. To determine the sample size for this pilot study, we examined different possible effect sizes and the associated sample size to detect a 60-minute per day reduction in total sedentary time. A 60 minute per day reduction was selected based on previous sedentary behavior reduction interventions, which resulted in reductions ranging from 47-110 minutes/day.\textsuperscript{16,29} The current study found an 18 minute per day difference between intervention and control groups, which is a Cohen’s d effect size of 0.3, or a small effect.\textsuperscript{57}

In order to be powered enough to detect a difference between groups in an intervention that results in a small effect, a sample size of 140 per condition would be required. This pilot study was therefore significantly underpowered to detect significant differences between groups in the primary outcome. Furthermore, it was likely underpowered to detect significant differences in other outcomes as well. However, these data do provide the needed data to inform the sample size calculations for an appropriately powered future randomized controlled trial, and thus the pilot feasibility trial was successful at achieving this key objective.

In addition to the lack of adequate power, another limitation to the analyses of blood pressure change was the lack of information on variables that can influence blood pressure, such as diet and stress.\textsuperscript{58-60} Also, individuals who were taking blood pressure medication were not asked whether they took their medication that day, which could
have a significant influence on their blood pressure assessment. In addition, participants were asked if they changed the number of blood pressure medications they were taking, but not whether the dosage had changed. The study would have benefitted from a measurement of the medication dosage, as well as behaviors that may have occurred on that day (e.g. drank coffee, exercised, etc.) to help control for factors other than sedentary time which might have influenced change in blood pressure readings.

Lastly, some participants encountered technical issues with intervention components. Three participants had issues with the text message delivery system and therefore only received the prompts for part of the intervention. Frustration with the text messages caused one participant to drop out and the engagement of the other two participants to wane during the intervention. There were also several complaints about the usability of the feedback website, which led many individuals to not using this component of the intervention. The website would have benefited from input by the target population to improve functionality and usefulness by making it easier to change prompts, making the website more mobile friendly, and limiting the number of graphs on the website. If these changes were made before implementation, it is possible that participants would have engaged more with this component.

6.3. Future Research

This dissertation study was the first sedentary behavior reduction intervention to focus on the sedentary behavior reduction of individuals with diagnosed hypertension. However, there were several limitations in the TAS4H study that would need to be addressed in future studies to continue to define the relationships between sedentary
behavior variables and blood pressure response. Given the high prevalence of individuals with hypertension both in the United States and worldwide, future studies examining this relationship have a large public health impact potential.

If Take a STAND 4 Health were to be implemented again, it would first need to be altered to make the intervention effective. Conducting a focus group to receive feedback from the target population on intervention components before implementation would assist with this goal. In addition, features that may be beneficial to include in a study like Take a STAND 4 Health would be the inclusion of self-monitoring of blood pressure. Self-monitoring has been shown to be an effective behavioral strategy, and may be an useful component to include in a sedentary behavior reduction intervention examining blood pressure. Having participants measure and record their blood pressure throughout the study may not only result in better blood pressure control, but could also help determine whether blood pressure is increasing as individuals stand more or whether there are other variables influencing the outcome.

The difference between messaging encouraging standing and stepping on sedentary behavior reduction was examined by Swartz et al., with those in the standing group reducing their sedentary behavior significantly more than the stepping group, but the effects of both behaviors on blood pressure was not examined in this study. In a study by Bailey et al., the differential effects of standing and physical activity on blood glucose were examined, and standing did not result in any significant improvement whereas physical activity did. In addition, in a study by Kozey-Keadle et al., participants
saw a significant reduction in blood pressure when encouraged to replace their sedentary behavior with light physical activity.\textsuperscript{15} Therefore, even if a message encouraging light physical activity results in lower sedentary behavior reduction, it may be a tradeoff worth making if it leads to better improvements in blood pressure.

6.4. Concluding Remarks

Sedentary behavior is an independent risk factor for poor health. Developing and testing effective behavioral interventions is necessary to reduce the excessive amount of sedentary time adults engage in. The TAS4H study tested the effectiveness of smartphone-mediated multi-component sedentary behavior reduction intervention on the sedentary behavior of adults with overweight or obesity and with or without hypertension. Unfortunately, the intervention was not successful in significantly reducing either the sedentary behavior or blood pressure of participants.

Recommendations for sedentary behavior interventions going forward are made based on the experiences in the TAS4H intervention, and the results of TAS4H provide insight into the possible role standing plays in blood pressure control.
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Appendix A

Take a STAND 4 Health IRB Approval Letter
INSTITUTIONAL REVIEW BOARD FOR HUMAN RESEARCH

APPROVAL LETTER for CONTINUED EXPEDITED REVIEW

Chelsea Larsen
Arnold School of Public Health
Department of Exercise Science
921 Assembly Street
Columbia, SC 29208

Re: Pro00079096 / Continuing Review Number: CR00028722
Dear Ms. Chelsea Larsen:

• This is to certify that the following proposal entitled Evaluating the Effects of a Sedentary Behavior Reduction Intervention on the Sedentary Time and Blood Pressure of Overweight/Obese Adults was reviewed and approved by the University of South Carolina Institutional Review Board (USC IRB) for continuation by Expedited review on 5/13/2019 (category 4 and 7).

Continuing Review is no longer required for this study; however, the Continuing Review form is used for the final report to the USC IRB.

PRINCIPAL INVESTIGATORS ARE TO ADHERE TO THE FOLLOWING APPROVAL CONDITIONS

• The research must be conducted according to the proposal/protocol that was approved by the USC IRB
• Changes to the procedures, recruitment materials, or consent documents, must be approved by the USC IRB prior to implementation
• If applicable, each subject should receive a copy of the approved date stamped consent document
• It is the responsibility of the principal investigator to report promptly to the USC IRB the following:
  o Unanticipated problems and/or unexpected risks to subjects
  o Adverse events effecting the rights or welfare of any human subject participating in the research study
• Research records, including signed consent documents, must be retained for at least (3) three years after the termination of the last IRB approval
• No subjects may be involved in any research study procedure prior to the IRB approval date
• At the time of study closure, a Continuing Review form is used for the final report to the USC IRB

The Office of Research Compliance is an administrative office that supports the University of South Carolina Institutional Review Board. If you have questions, contact Lisa M. Johnson at lisaj@mailbox.sc.edu or (803) 777-6670.

Sincerely,

Lisa M. Johnson
ORC Assistant Director and IRB Manager

The Office of Research Compliance is an administrative office that supports the University of South Carolina Institutional Review Board. If you have questions, contact Lisa M. Johnson at lisaj@mailbox.sc.edu or (803) 777-6670.

Sincerely,

Lisa M. Johnson
ORC Assistant Director and IRB Manager
Appendix B

Recruitment Messages and Flyers
Facebook Messages

Do you spend much of your day sitting? Do you also take medication to control your blood pressure? If so, join the Take a STAND 4 Health study, a free text-based sedentary behavior intervention conducted by researchers at the University of South Carolina! Our team of experienced interventionists will help you reduce your time sitting!

Are you controlling your blood pressure with medication and interested in reducing your time spent sitting? Learn more about joining the Take a STAND 4 Health study, a text-based sedentary behavior intervention conducted at the University of South Carolina!

Twitter Message

Do you spend most of your day sitting and live/work in the Columbia area? If so, join Take a STAND 4 Health, a free, smartphone-based sitting time reduction study! Click the link below to learn more and apply! https://is.gd/TakeaSTAND4Health

Listserv Announcement

Do you find yourself spending most of your day sitting, with long periods of time in between breaks? Are you also overweight or obese? If so, you may be eligible for an exciting new research study at USC! The Take a STAND 4 Health study is designed to help you decrease the time you spend sitting each day by answering prompts you get on your smartphone. The purpose of the study is to see how sitting less may improve your blood pressure, and it is currently recruiting adults who work or live in the Columbia area. If you’re interested in participating, please click on the link below to learn more and apply!

https://is.gd/TakeaSTAND4Health
Do you have high blood pressure?

☑ Are you overweight?
☑ Do you spend a large part of your day sitting?
☑ Do you own a smartphone?

If yes, consider enrolling in the
Take a STAND 4 Health study!

Take a STAND 4 Health studies whether a text message prompting you to stand will lower your blood pressure.

*Use your smartphone to sit less!*

Interested? Email calarsen@email.sc.edu or visit https://is.gd/TakeaSTAND4Health to learn more and to see whether you are eligible!

UNIVERSITY OF SOUTH CAROLINA
Arnold School of Public Health
☑ Do you find yourself sitting most of the day?

☑ Do you want to get healthier but don’t have time to add more exercise?

☑ Do you take blood pressure medication?

☑ Do you live or work in the Columbia area?

If yes, then you may be eligible for a new study at USC!

Take a STAND 4 Health studies whether a text message prompting you to stand will lower your blood pressure.

Use your smartphone to sit less!

Interested? Email calarsen@email.sc.edu or visit https://is.gd/TakeaSTAND4Health to learn more!
Appendix C

Take a STAND 4 Health Online Eligibility Screener
Thank you for your interest in the Take a STAND 4 Health study! This study is being conducted by Chelsea Larsen in the Department of Exercise Science, Arnold School of Public Health at the University of South Carolina.

The purpose of this study is to look at the relationship between the amount of time a person spends sitting (what we call sedentary behavior) and their blood pressure and examine whether decreasing sedentary behavior helps improve blood pressure. Study participation lasts for about 3 months and consists of an initial assessment followed by 8 weeks and two additional assessments. During this time, individuals will come into our office for an in-person session, during which they will receive personalized information about their sedentary behavior and strategies to reduce it, followed by texts that will be delivered to their smartphone to help them implement these strategies. The program is offered at no charge to you, and all participants will receive the intervention at some time during their participation, with some receiving it immediately and others waiting for a month before they get the program.

To be eligible, individuals must be overweight or obese [a body mass index (weight [kg]/height [m]2) between 25 and 50], own a smartphone that is accessible during the day, and be in the Columbia, South Carolina area.

If you have any other questions about the study that you would like answered before completing the application, you can call Chelsea Larsen at 931-572-7640 or email her at calarsen@email.sc.edu. If you do not have any additional questions and you are still interested in learning whether you are eligible to participate in the Take a STAND 4 Health study, please complete the following screening questionnaire! You will answer a few questions about yourself to determine whether you are eligible for this study. All information that you provide will be confidential and available only to research personnel.

If you would like to participate, please continue with the survey to see if you are eligible for the Take a STAND 4 Health study.

Thank you for your consideration.

Additional study information:
Title: Take a STAND 4 Health Study
PI: Chelsea Larsen, MPH, Doctoral Student in Exercise Science, University of South Carolina
By completing and submitting the following online form, I am giving my consent to be considered as a participant for the Take a STAND 4 Health study taking place in the Department of Exercise Science at the University of South Carolina. I consent to be contacted by study personnel to further determine my eligibility for the study. I understand that I can withdraw at any time without penalty.

[ ] I agree

[ ] I Disagree

What is your sex?
[ ] Male
[ ] Female

What is your age?
__________ years old

When is your birthday?
MM/DD/YR

What is your weight (in pounds)?
__________ pounds

What is your height (in inches)?
________ inches

BMI (please click on the box below to continue)
[ ]

Do you own a smartphone?
[ ] Yes
[ ] No

What type of smartphone do you own?
[ ] Android
[ ] IPhone
[ ] Other
Can you access the internet from your smartphone?
[ ] Yes
[ ] No

Are you able to access your smartphone during the day, on both a week day and weekend day?
[ ] Yes
[ ] No

Do you live or work within 30 miles of the University of South Carolina- Columbia?
[ ] Yes
[ ] No

Do you have difficulty standing or walking for short periods of time?
[ ] Yes
[ ] No

Are you currently undergoing treatment for a serious disease, such as cancer?
[ ] Yes
[ ] No

Are you currently pregnant or have you given birth within the last 6 months?
[ ] Yes
[ ] No

Are you currently participating in another research study of any kind?
[ ] Yes
[ ] No

Please answer the following questions about your sedentary behavior (time you spend sitting) to the best of your ability.

On a typical WEEK DAY in the past week, how much time do you spend (from the time you wake up until you go to bed) SITTING OR LYING while doing the following activities?

<table>
<thead>
<tr>
<th>Activity</th>
<th>None</th>
<th>15 min or less</th>
<th>30 min</th>
<th>1 HR</th>
<th>2 HR</th>
<th>3 HR</th>
<th>4 HR</th>
<th>5 HR</th>
<th>6+ HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting or lying and watching television (including DVDS) on a TV, smartphone, or tablet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

167
| Sitting or lying and playing computer, video, or smartphone/tablet games |   |   |   |   |   |   |
| Sitting or lying and listening to music on the radio, a MP3 player, or iPod |   |   |   |   |   |   |
| Sitting or lying and talking or texting on the phone |   |   |   |   |   |   |
| Sitting or lying and working on the computer or doing paperwork |   |   |   |   |   |   |
| Sitting or lying and reading a book, magazine, or tablet/kindle |   |   |   |   |   |   |
| Sitting or lying and playing a musical instrument |   |   |   |   |   |   |
| Sitting or lying and doing artwork or crafts |   |   |   |   |   |   |
| Sitting or lying in a car, bus, or train |   |   |   |   |   |   |

HR = Hours

On a typical WEEKEND Day in the past WEEK, how much time do you spend (from the time you wake up until you go to bed) SITTING or LYING while doing the following activities?

<table>
<thead>
<tr>
<th>None</th>
<th>15 min or less</th>
<th>30 min</th>
<th>1 HR</th>
<th>2 HR</th>
<th>3 HR</th>
<th>4 HR</th>
<th>5 HR</th>
<th>6+ HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting or lying and watching television (including DVDs) on a TV, smartphone, or tablet</td>
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<tr>
<td>Activity</td>
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</tr>
<tr>
<td>Sitting or lying and playing computer, video, or smartphone/tablet games</td>
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<tr>
<td>Sitting or lying and listening to music on the radio, a MP3 player, or iPod</td>
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<tr>
<td>Sitting or lying and talking or texting on the phone</td>
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<tr>
<td>Sitting or lying and working on the computer or doing paperwork</td>
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<td></td>
</tr>
<tr>
<td>Sitting or lying and reading a book, magazine, or tablet/kindle</td>
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<td></td>
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</tr>
<tr>
<td>Sitting or lying and playing a musical instrument</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sitting or lying and doing artwork or crafts</td>
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<td></td>
</tr>
<tr>
<td>Sitting or lying in a car, bus, or train</td>
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</tbody>
</table>

HR= Hours

Thank you for your interest in the Take a STAND 4 Health study! Please answer a few more questions so that a member of our research staff can contact you by phone to explain more details about the study to you and complete the screening for participation in the exciting new program.

What is your name?
_________________________

What is the best phone number to reach you at?
XXX-XXX-XXXX

What is the best email address to reach you at?
_________________________

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What is the best time of day to reach you by phone?
[ ] Morning
[ ] Afternoon
[ ] Evening
[ ] No preference

Thank you! We will call you within the next 3-4 days. Please click "submit" and we will talk to you soon!
Appendix D

Take a STAND 4 Health Phone Eligibility Screener
Hello, this is Chelsea from the Take a STAND 4 Health study at USC. May I speak to [name]?

I am following up on your interest in the Take a STAND 4 Health program. First, I want to tell you a little about the program and then I'll ask you some questions. You may remember that the Take a STAND 4 Health study is a sedentary behavior, which is the fancy word for sitting time, reduction intervention designed to help you decrease the time you spend sitting each day by finding ways to stand and move more during your normal daily routine. The study is approximately 3 months long, with 4 weeks of intervention. You will be measured 3 times over the 3 months, which includes wearing a waterproofed accelerometer (activPAL) on your thigh. There are two groups in the study, and the only difference is when the groups will receive the intervention. When you will start the intervention will be determined at random. If you are still interested, I would like to take about 10 minutes of your time to see if you are eligible to take the next step in screening for this program. Is now a convenient time or should I call back at another time?

Before I begin, I would like to ask how you heard about the Take a STAND 4 Health program. Was it?
[ ] UofSC
[ ] Email from Briana (iREACH)
[ ] Flyer at your doctor’s office
[ ] Flyer someone else
[ ] From someone you know
[ ] Facebook
[ ] Other

I would like to confirm your email as [email]. Is this still the best email to reach you at?
[ ] Yes
[ ] No

I would like to confirm your phone number as [phone]. Is this still the best phone number to reach you at?
[ ] Yes
[ ] No

How long does it take you to get from your home to USC, door to door?
[ ] 60 minutes or less
[ ] More than 60 minutes

IF SAY 60 MINUTES OR LESS: What is your address?

_____________________________
IF SAY MORE THAN 60 MINS:

I'm sorry Mr. /Ms. [name]. It has been our experience that people who have a very long trip to our office for data assessments will be unable to complete the program. Therefore, we need to exclude people who live that far away. Thank you for your interest though. We can put you on a list for future sedentary behavior studies. Would you like for us to do that?

[ ] Yes
[ ] No

Are you planning a major change in your schedule or taking a vacation lasting longer than 1 week in the next 4 months?

[ ] Yes
[ ] No

If yes, how long and when?
_________________________

IF TAKING A LONG VACATION:
I'm sorry Mr. /Ms. [name]. The Take a STAND 4 Health study is evaluating different strategies for reducing sedentary time during individuals' standard day to day routines. In order to answer this question, we need to follow participants for at least 2 months with no major alternations. Since you will have time periods that are "abnormal", we would not be able to get the information needed for the study, and therefore, we cannot enroll you in the program. Thank you for your interest though. We can put you on a list for future sedentary behavior studies. Would you like for us to do that?

[ ] Yes
[ ] No

Are you currently taking medication for your high blood pressure?

[ ] Yes
[ ] No

IF NOT TAKING MEDICATIONS:
I'm sorry Mr. /Ms. [name]. The target population for the Take a STAND 4 Health study is individuals who are currently taking medication to control their high blood pressure. Since you are not currently taking medications for this purpose, you are ineligible for this study. Thank you for your interest though. We can put you on a list for future sedentary behavior studies. Would you like for us to do that?

[ ] Yes
[ ] No

What other prescription medications or pills are you taking?

[ ] none
[ ] Other medications

**What are these medications for?**

Have you had a checkup from your physician in the last 6 months?
[ ] Yes
[ ] No

**IF HAVEN'T HAD A CHECK UP IN LAST 6 MONTHS:**
I'm sorry Mr. /Ms. [name]. Since you have not been to your physician within the last 6 months, we cannot be sure that you have the correct medication dosage to control your hypertension. Since the target population for the Take a STAND 4 Health study is individuals who are currently taking medication to control their high blood pressure, you are ineligible for this study. Thank you for your interest though. We can put you on a list for future sedentary behavior studies. Would you like for us to do that?
[ ] Yes
[ ] No

Are you currently pregnant, plan to become pregnant during the next 6 months, or have you given birth in the past 6 months?
[ ] Yes
[ ] No

**IF PLAN TO BECOME PREGNANT OR IS PREGNANT:**
I'm sorry Ms. [name]. The Take a STAND 4 Health study cannot take women who [insert criteria here] because of the effect that weight fluctuations during or after pregnancy can have on blood pressure. Thank you for your interest though. We can put you on a list for future sedentary behavior studies. Would you like for us to do that?
[ ] Yes
[ ] No

Do you have any major health conditions or disabilities that would keep you from standing up or lightly walking? In other words, do you have difficulty standing up or walking for short periods of time?
[ ] Yes
[ ] No

**IF THEY DO HAVE MAJOR HEALTH CONDITIONS:**
I'm sorry Mr. /Ms. [name]. The goal of the Take a STAND 4 Health study is to reduce sedentary time by increasing the time participants spend standing or walking. Since you are unable to perform these tasks, you are ineligible for the study. Thank you for your interest though. We can put you on a list for future sedentary behavior studies. Would you like for us to do that?
Are you currently participating in another research study?
[ ] Yes
[ ] No

*IF STUDY THEY'RE PARTICIPATING IN IS A WEIGHT LOSS, DIET, PHYSICAL ACTIVITY, OR STRESS MANAGEMENT STUDY:*
I'm sorry Mr. /Ms. [name]. In order for us to determine the effectiveness of the Take a STAND 4 Health program, we need to be sure you are not currently participating in other behavioral interventions. Thank you for your interest though. We can put you on a list for future sedentary behavior studies. Would you like for us to do that?
[ ] Yes
[ ] No

Are you able to access your smartphone during the day, both on a weekday and weekend day?
[ ] Yes
[ ] No

*IF NOT ABLE TO ACCESS PHONE DURING THE DAY:*
I'm sorry Mr. /Ms. [name]. Part of the Take a STAND 4 Health intervention is engaging with a texts that you receive throughout the day. Since you are unable to access your phone during the day, you are ineligible for this study. Thank you for your interest though. We can put you on a list for future sedentary behavior studies. Would you like for us to do that?
[ ] Yes
[ ] No

What type of cell phone will you have to start this study?
[ ] Android, such as LG or Samsung
[ ] iPhone
[ ] Other

Can you receive unlimited text messages?
[ ] Yes
[ ] No

*IF NO:*
Part of the Take a STAND 4 Health intervention is engaging with 6-10 texts that you receive each day for the duration of the study. Since you do not have unlimited texts, we want to verify that you are agreeing to let us send you daily texts that will use some of your texts. If you are not comfortable with us using your texts, you will not be eligible
for this particular study. However, we can put you on a list for future sedentary behavior studies. Are you consenting to let us send you 6-12 daily steps for the duration of the study?
[ ] Yes
[ ] No

Thank you [name]! You meet the criteria to attend the Take a STAND 4 Health orientation session! At this session you will learn more about the Take a STAND 4 Health program, have the opportunity to ask questions and review a consent form that describes your participation in a research study. Then, if you are still interested, I will take your blood pressure, height, weight, and waist circumference. We will then schedule you for your randomization visit. I would like to go ahead and schedule you now for an orientation session, which will be at the University of South Carolina campus.

[Check the planner for available dates]

We will confirm this appointment by email and we will also send you directions about how to find our offices. If you cannot keep your appointment, please call us at least 2 days beforehand to reschedule.

There are a few things to remember for this session:

Please be sure to bring reading glasses, if you need them, as we will be reviewing a consent form.

Please also bring your calendar as we'll invite you to schedule your randomization visit following the end of orientation.

Lastly, please wear shorts or an outfit that you can affix a device to your thigh in and a top that you can have your blood pressure taken in (i.e. a short sleeved shirt, a tank top, a dress with no sleeves, etc.).

Do you have any questions?

We look forward to seeing you at orientation!
# Take a STAND 4 Health Study

<table>
<thead>
<tr>
<th>You are at high risk of being a sedentary person if you are:</th>
<th>Negative health outcomes even if</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overweight/Obese</td>
<td>Have a chronic disease</td>
</tr>
</tbody>
</table>

The Take a STAND 4 Health study is a sedentary behavior reduction intervention that will:
- Look at your sitting time and blood pressure
- See whether decreasing your sitting time improves your blood pressure

**What will you learn in the Take a STAND 4 Health study?**
- Your personal sitting patterns
- Strategies to help you reduce the time you spend sitting

**What are the two groups you could be randomized to?**
- You will be assigned by chance to 1 of 2 groups:
  - Immediate Intervention
  - Delayed Intervention

Both groups will receive **THE SAME** intervention, just at different times.
Personalized Assessment

Texts, Website and Calls

<table>
<thead>
<tr>
<th>Name</th>
<th>Time</th>
<th>Duration</th>
<th>Recurring</th>
<th>Edit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wednesday, Aug/01 - Break 1</td>
<td>9:30am</td>
<td>5 min</td>
<td>yes</td>
<td>Edit</td>
</tr>
<tr>
<td>Wednesday, Aug/01 - Break 2</td>
<td>10:45am</td>
<td>5 min</td>
<td>yes</td>
<td>Edit</td>
</tr>
<tr>
<td>Wednesday, Aug/01 - Break 3</td>
<td>11:00am</td>
<td>5 min</td>
<td>yes</td>
<td>Edit</td>
</tr>
<tr>
<td>Wednesday, Aug/01 - Break 4</td>
<td>1:05pm</td>
<td>10 min</td>
<td>yes</td>
<td>Edit</td>
</tr>
<tr>
<td>Wednesday, Aug/01 - Break 5</td>
<td>3:00pm</td>
<td>10 min</td>
<td>yes</td>
<td>Edit</td>
</tr>
<tr>
<td>Wednesday, Aug/01 - Break 6</td>
<td>5:00pm</td>
<td>5 min</td>
<td>yes</td>
<td>Edit</td>
</tr>
<tr>
<td>Wednesday, Aug/01 - Break 7</td>
<td>7:00pm</td>
<td>10 min</td>
<td>yes</td>
<td>Edit</td>
</tr>
<tr>
<td>Wednesday, Aug/01 - Break 8</td>
<td>8:00pm</td>
<td>10 min</td>
<td>yes</td>
<td>Edit</td>
</tr>
</tbody>
</table>

Yesterday 12:50 PM

Hey! It's time to take your 5 minute break. Please follow the link and make a selection

Tap to Load Preview
dms.sph.sc.edu

Right now, I'm:

- Taking my 5 minute break
- Needing to snooze my 5 minute break for 15 minutes
- Choosing to skip my 5 minute break
- Already standing for my 5 minute break
**How much will the program cost you?**

The program is **FREE** to you! The only cost is your transportation to the University of South Carolina for assessments.

**Who is eligible to receive the program? Adults who are/have:**

- 18 years or older who are overweight or obese
- Living or working within 30 miles of USC
- Willing to wear the activPAL for baseline assessment
- An average self-reported sedentary time of least 7 hours
- Willing to be randomized to either group

---

**You’re interested! Great! So, what’s next?**

- Sign the consent form
- We will measure your:
  - Height
  - Weight
  - Waist circumference
  - Blood pressure
- Give you an activPAL to wear for 7 days
- Schedule your randomization visit for 1 week from now

**You’d like to think about it...**

No problem! The Take a STAND 4 Health program isn’t for everyone. You’re welcome to think about it and contact us if you’re still interested in it.

Also, if you’re not interested, but know someone who might be, please pass along information about the program!
Appendix F

TAS4H Consent Form
UNIVERSITY OF SOUTH CAROLINA

CONSENT TO BE A RESEARCH SUBJECT

Take a STAND 4 Health Study

KEY INFORMATION ABOUT THIS RESEARCH STUDY:

There is emerging evidence that an excessive amount of sitting time (sedentary behavior) is linked with increased risk of negative health outcomes, regardless of an individual's physical activity levels. This is concerning considering Americans spend over half of the waking day sitting, and individuals who are overweight or obese and/or have a chronic disease (e.g. hypertension) are likely to spend even more time sitting. A few experimental studies have looked at the effects of reducing sitting time on blood pressure and show some promising outcomes. However, these studies lasted for only a day, so it is unclear how decreasing the time spent sitting may influence blood pressure over a longer period of time. The purpose of this study is to look at the relationship between the amount of time a person spends sitting and their blood pressure, as well as whether decreasing the time spent sitting helps improve blood pressure.

Everyone in this study will receive a 4-week program designed to reduce the time they spend sitting. You will be assigned by chance to receive the program either the first or second half of the study. The program will be personalized to your unique pattern of sitting time and consists of an in-person session, 4 weeks of texts which will act as reminders of when it is time to interrupt your sitting, and two coaching phone calls. You will also be given access to a website to help track your sitting time.

There are few risks for participating in research to reduce your sitting time. However, there is a risk that a breach in privacy may occur, resulting in the discovery of your identity as a research subject (i.e. your name) by other people. The steps we will take to prevent or lessen this risk are outlined later in this document.

Participation in this study is voluntary. You are free to not participate or stop participating at any time, for any reason, without negative consequences.

PURPOSE AND BACKGROUND

You are being invited to participate in a research study conducted by Chelsea Larsen, who is a doctoral candidate in the Department of Exercise Science at the University of South Carolina. The purpose of this study is to evaluate whether the program to reduce sitting time results in a significant decrease in sitting time and whether that reduction results in any change in blood pressure.

You are being asked to participate in this study because you are over the age of 18, are overweight/obese, and have controlled high blood pressure. The study is being done at
the University of South Carolina Columbia campus. Up to 75 individuals will be recruited and we will randomize the first 36 eligible volunteers.

This form explains what you will be asked to do as part of the study should you decide to participate. Please read it carefully and feel free to ask questions before you make a decision about participating.

PROCEDURES:
If you agree to participate in this study, you will do the following:

Following baseline data collection, you will be assigned at random by an envelope to participate in one of two treatment groups: 1) the Immediate Intervention group, which will receive the program to reduce sitting time for the first four weeks of the study and then be followed for another 4 weeks or the 2) Delayed Intervention group, which will receive the 4-week program to reduce sitting time in the second half of the 8-week study. The only difference between groups is when you will receive the program.

At three different points over the course of three months, you will attend sessions to measure your health status. The first measurement will occur when you first begin the study. Follow up sessions will occur after four and then eight weeks later. Each assessment will require you to come to the University of South Carolina campus in Columbia to allow us to measure your blood pressure, weight and waist circumference. Before these visits, you will complete an online survey about your lifestyle behaviors such as physical activity and sedentary time.

You will be asked to wear an activPAL accelerometer that will track your physical activity and sedentary behavior. You will wear the device for seven days at three different time points: after the orientation session, at four weeks, and at eight weeks. The activPAL is a small device that you will wear strapped to your thigh for seven days which records your physical activity and your sleep. You will also be asked to keep a log recording the times you remove the device. You will either come into the office to return the activPAL after 7 days or mail it back to us in a pre-stamped, postage paid envelope.

As part of the 4-week long program to reduce sitting time, you will also be asked to attend an in-person session to develop your personalized plan as well as visit the study website regularly, respond to daily texts and engage in biweekly phone calls. Some of you will get the program to reduce your sitting time right after you are randomized (during your second visit) and others will get it after your four-week assessment. As previously mentioned, randomization will determine whether you are in the group that gets Immediate Intervention or the group that gets Delayed Intervention, which will be four weeks later. Randomization is like a flip of a coin and means that you cannot chose which group you are in.
The timing of study participation is shown in Table 1 below. All in-person assessment visits will take 30 minutes or less. Online surveys will take about 30 minutes to complete. The in-person session visit (first session of the program to reduce sitting time) will take approximately 30 minutes and the two coaching calls will last 10 minutes each and will occur in weeks 1 and 3 of the program to reduce sitting time.

During your program session, we will identify your sitting patterns and create an action plan for how to reduce your daily sitting time, including identifying the best times for you to receive the texts that will be sent to you over the 4 weeks to remind you about reducing your sitting time.

Table 1. Study Implementation Timeline

<table>
<thead>
<tr>
<th>Visit 1</th>
<th>Visit 2</th>
<th>Visit 3</th>
<th>Visit 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orientation Session</td>
<td>Randomization Visit (2 week later)</td>
<td>Initial Assessment</td>
<td>1 2 3 4 5 6 7 8 9 10 11</td>
</tr>
<tr>
<td>Be consented</td>
<td>Return the activPAL</td>
<td>Return for 4-week measures of blood pressure, weight and waist AND have completed online survey</td>
<td>Return for 8-week measures of blood pressure, weight and waist AND have completed online survey</td>
</tr>
<tr>
<td>Wear the activPAL for the next 7 days</td>
<td>In-Person Session</td>
<td>Website and testing intervention only</td>
<td>Return activPAL</td>
</tr>
<tr>
<td>Complete online survey</td>
<td>Phone Call</td>
<td>Phone Call</td>
<td>Phone Call</td>
</tr>
<tr>
<td>Have in-person measurements of blood pressure, height, weight, waist circumference</td>
<td>Schedule 4-week assessment</td>
<td>No contact</td>
<td>Phone call</td>
</tr>
<tr>
<td>Return the activPAL</td>
<td>Receive activPAL to wear for 7 days</td>
<td>Receive activPAL to wear for 7 days</td>
<td></td>
</tr>
</tbody>
</table>

Immediate Group= Immediate Intervention Group

Delayed Group= Delayed Intervention Group

The content of the program to reduce sitting time will be the same in both the Immediate and Delayed Intervention groups and will focus on developing new habits around reducing your sedentary time. You will not interact with other participants. This intervention is individualized and tailored to your unique patterns, and you will interact only with a member of the research staff, who will be your “coach”. After the in-person session, the program will consist of texts and using the website, as well as two phone calls from your coach.

The texts are designed to remind you to move and will ask you to reply whether you stood up or not. This information you provide after receiving each text will be summarized in the feedback that you will receive each day. This feedback includes a review of that day’s scheduled sitting breaks and your total sitting time reduction. The phone calls are designed to discuss any concerns you have about the program and to provide an opportunity to revise your plans to reduce your sitting time, if you need to.
make changes. The Immediate Intervention group will continue to receive texts and have access to the website during the second 4-week period of the study but will receive no phone calls during the second period.

**DURATION**

Participation in the study involves four in-person visits over a period of up to 3 months. Each assessment visit will last 30 minutes or less. You will be asked to complete online surveys at three times, which will take up to 30 minutes to complete each time. Participation in the program also involves interaction with the study website and texts, as well as two phone calls with a member of the research staff, each of which will last for approximately 10 minutes. We estimate that these activities will take approximately 1-2 hours per week to complete.

**RISKS/DISCOMFORTS**

There are minimal risks for participating in a sitting time reduction study since the goal of the program is to reduce sitting time by standing or engaging in light physical activity. The information you provide will be kept private and will not be shared with non-research staff. No identifiable information about you will ever be published or shared without your consent. All study results will be presented in aggregate form with no identifiable information about individuals. However, even though there will be steps taken to protect your identity, it is possible that a breach of privacy could occur, which would result in others knowing your identity as a research participant.

**BENEFITS**

You may benefit from participating in this study by learning about the risks associated with extended sitting time, and about your personal sitting patterns, and strategies to reduce how much you sit. You may also experience an increase in light physical activity and/or a decrease in your blood pressure, both of which can have health benefits. Additionally, the study may benefit the greater public by identifying effective methods for reducing sitting time.

**COSTS**

There is no cost for participation in this study other than possible transportation costs to and from the research site and your time.

**PAYMENT TO PARTICIPANTS**

There are no payments for you. However, you will be offered the opportunity to participate in a raffle for small prizes at 4-weeks and 8-weeks after completing follow-up data collection visits as a token of appreciation for your participation.
USC STUDENT PARTICIPATION

Participation in this study is voluntary. You are free not to participate, or to stop participating at any time, for any reason without negative consequences. Your participation, non-participation, and/or withdrawal will not affect your grades or your relationship with your professors, college(s), or the University of South Carolina.

If research credit is required for successful course completion, other alternative means for obtaining credit are available and you may discuss these options with your course instructor.

CONFIDENTIALITY OF RECORDS

Unless required by law, information that is obtained in connection with this research study will remain confidential. Any information disclosed would be with your express written permission. Any documents with your information will be securely stored in locked files and on password protected computers. Additionally, the results of the research study may published or presented, but information will be aggregated so your name or other identifying information will not be included.

VOLUNTARY PARTICIPATION

Participation in this research study is voluntary. You are free not to participate or to stop participating at any time, for any reason, without negative consequences. In the event that you do withdraw from this study, the information you have already provided will be kept in a confidential manner. If you wish to withdraw from the study, please call the Principal Investigator, Chelsea Larsen, at (803-777-2702) or email her at calarsen@email.sc.edu.

STUDY WITHDRAWAL

You may choose to withdraw from the study at any point. If you experience medical problems during the study and your continued participation presents health risks, you will be withdrawn. Additionally, the investigators reserve the right to end your participation in the study at any time.

QUESTIONS ABOUT THE STUDY:

I have been given a chance to ask questions about this research study. These questions have been answered to my satisfaction. If I have more questions about my participation in this study or study-related injury, I am to contact Chelsea Larsen at 803-777-2702 or calarsen@email.sc.edu.
If I have any questions, problems, or concerns, desire further information or wish to offer input, I may contact Lisa Marie Johnson, IRB Manager, Office of Research Compliance, University of South Carolina, 1600 Hampton Street, Suite 414D, Columbia, SC, 29208, phone: (803)-777-7095 or email: Lisaj@mailbox.sc.edu. This includes any questions about my rights as a research subject in this study.

I agree to participate in this study. I have been given a copy of this form for my own records.

If you wish to participate, you should sign below.

__________________________________________
Printed Name of Subject

__________________________________________
Signature of Subject                     Date

__________________________________________
Printed Name of Person Obtaining Consent

__________________________________________
Signature of Person Obtaining Consent     Date
Appendix G

TAS4H Baseline Survey
What is your name?
_______________

In the event of an emergency, what is the name of the person we could contact?
_______________

What is the phone number of your emergency contact?
XXX-XXX-XXXX

What is the relationship between you and your emergency contact?
[ ] Significant Other/Partner/Spouse
[ ] Parent
[ ] Child
[ ] Coworker
[ ] Friend
[ ] Other

Which of the following best describes your race?
[ ] American Indian or Alaskan Native
[ ] Asian
[ ] Native Hawaiian or other Pacific Islander
[ ] Black or African American
[ ] White
[ ] Other

Which of the following best describes your ethnicity?
[ ] Hispanic or Latino
[ ] Not Hispanic or Latino

What is your marital status?
[ ] Married
[ ] Divorced
[ ] Widowed
[ ] Separated
[ ] Never Married

Please select the option that best describes your education level/the years of school you have completed.
[ ] Grade School (6 years or less)
[ ] Junior High School (7-9 years)
[ ] High School (10-12 years)
[ ] Vocational Training (beyond high school) or Associates Degree
[ ] Some College (less than 4 years)
[ ] College/University Degree
[ ] Graduate or Professional Education

**What is your current employment status?**

[ ] Full time employment  
[ ] Part time employment  
[ ] Unemployed/looking for work  
[ ] Unemployed/Not looking for work  
[ ] Student  
[ ] Retired  
[ ] Unable to work  
[ ] Other

**Are you taking any prescription medications? (NOTE: If you are taking more than one medication for a condition, please write down all medications.)**

[ ] Yes  
[ ] No

**How many prescription medications are you taking?**

[ ] 1  
[ ] 2  
[ ] 3  
[ ] 4  
[ ] 5  
[ ] 6  
[ ] More than 6

Thinking about your prescription medication list, what is the name of the 1st medication that you are taking?

____________________________________

**What do you take this medication for?**

____________________________________

Thinking about your prescription medication list, what is the name of the 2nd medication that you are taking?

____________________________________

**What do you take this medication for?**

____________________________________

Thinking about your prescription medication list, what is the name of the 3rd medication that you are taking?

____________________________________
What do you take this medication for?
____________________

Thinking about your prescription medication list, what is the name of the 4th medication that you are taking?
____________________

What do you take this medication for?
____________________

Thinking about your prescription medication list, what is the name of the 5th medication that you are taking?
____________________

What do you take this medication for?
____________________

Thinking about your prescription medication list, what is the name of the 6th medication that you are taking?
____________________

What do you take this medication for?
____________________

What are the names of your other medications that you have not already listed and what do you take them for?
____________________

Are you taking any over-the-counter (OTC) or non-prescription medications, such as fish oil, daily ibuprofen, etc.?
[ ] Yes
[ ] No

How many OTC/non-prescription medications are you currently taking?
[ ] 1
[ ] 2
[ ] 3
[ ] 4
[ ] 5
[ ] 6

Thinking about your OTC/non-prescription medication list, what is the name of the 1st medication you are taking?
____________________
What do you take this medication for?
______________

Thinking about your OTC/non-prescription medication list, what is the name of the 2nd medication you are taking?
_____________________

What do you take this medication for?
______________

Thinking about your OTC/non-prescription medication list, what is the name of the 3rd medication you are taking?
_____________________

What do you take this medication for?
______________

Thinking about your OTC/non-prescription medication list, what is the name of the 4th medication you are taking?
_____________________

What do you take this medication for?
______________

Thinking about your OTC/non-prescription medication list, what is the name of the 5th medication you are taking?
_____________________

What do you take this medication for?
______________

Thinking about your OTC/non-prescription medication list, what is the name of the 6th medication you are taking?
_____________________

What do you take this medication for?
______________

What are the names of your other OTC/non-prescription medications that you have not already listed and what do you take them for?
_______________________
How many prescription medications are you taking for your blood pressure?
[ ] 1  
[ ] 2  
[ ] 3  
[ ] 4  
[ ] 5  
[ ] 6 or more  
[ ] I am not taking any medication for my blood pressure

Thinking about your prescription medication(s) for blood pressure, what is the name of the 1st medication that you are taking?
__________________

Thinking about your prescription medication list, what is the name of the 2nd blood pressure medication that you are taking?
__________________

Thinking about your prescription medication list, what is the name of the 3rd blood pressure medication that you are taking?
__________________

Thinking about your prescription medication list, what is the name of the 4th blood pressure medication that you are taking?
__________________

Thinking about your prescription medication list, what is the name of the 5th blood pressure medication that you are taking?
__________________

Thinking about your prescription medication list, what is the name of the 6th blood pressure medication that you are taking?
__________________

What are the names of your other blood pressure medications that you have not already listed and what do you take them for?
__________________

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at school, at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.
Think about all the **vigorous** activities that you did in the **last 7 days**. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think **only** about those physical activities that you did for at least 10 minutes at a time.

During the last 7 days, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling? Think about **only** those physical activities that you did for at least 10 minutes at a time.

Days: XX

**How much time in total did you usually spend on one of those days doing vigorous physical activities?**

Hours: XXX
Minutes: XXXX

Again, think **only** about those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

Days: XX

**How much time in total did you usually spend on one of those days doing moderate physical activities?**

Hours: XXX
Minutes: XXXX

During the last 7 days, on how many days did you walk for at least 10 minutes at a time? This includes walking at work and at home, walking to travel from place to place, and any other walking that you did solely for recreation, sport, exercise or leisure.

Days: XX

**How much time in total did you usually spend walking on one of those days?**

Hours: XXX
Minutes: XXXX

The last question is about the time you spent **sitting** on weekdays while at work, at home, while doing course work and during leisure time. This includes time spent
sitting at a desk, visiting friends, reading traveling on a bus or sitting or lying down to watch television. During the last 7 days, how much time in total did you usually spend *sitting* on a *week day*?

Hours: XXX
Minutes: XXXX

Please answer the following questions about your sedentary behavior (time you spend sitting) to the best of your ability.

On a typical WEEK DAY in the past week, how much time do you spend (from the time you wake up until you go to bed) *SITTING OR LYING* while doing the following activities?

<table>
<thead>
<tr>
<th>Activity</th>
<th>None</th>
<th>15 min or less</th>
<th>30 min</th>
<th>1 HR</th>
<th>2 HR</th>
<th>3 HR</th>
<th>4 HR</th>
<th>5 HR</th>
<th>6+ HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting or lying and watching television (including DVDS) on a TV, smartphone, or tablet</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Sitting or lying and playing computer, video, or smartphone/tablet games</td>
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</tr>
<tr>
<td>Sitting or lying and listening to music on the radio, a MP3 player, or iPod</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Sitting or lying and talking or texting on the phone</td>
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<td></td>
</tr>
<tr>
<td>Sitting or lying and working on the computer or doing paperwork</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying and reading a book, magazine, or tablet/kindle</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
On a typical WEEKEND Day in the past WEEK, how much time do you spend (from the time you wake up until you go to bed) SITTING or LYING while doing the following activities?

<table>
<thead>
<tr>
<th>Activity</th>
<th>None</th>
<th>15 min or less</th>
<th>30 min</th>
<th>1 HR</th>
<th>2 HR</th>
<th>3 HR</th>
<th>4 HR</th>
<th>5 HR</th>
<th>6+ HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting or lying and watching television (including DVDs) on a TV, smartphone, or tablet</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sitting or lying and playing computer, video, or smartphone/tablet games</td>
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<tr>
<td>Sitting or lying and listening to music on the radio, a MP3 player, or iPod</td>
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<tr>
<td>Sitting or lying and talking or texting on the phone</td>
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<tr>
<td>Sitting or lying and working on the computer or doing paperwork</td>
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<tr>
<td>Sitting or lying and reading a book, magazine, or tablet/kindle</td>
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<tr>
<td>Activity</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
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<td>---</td>
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</tr>
<tr>
<td>Sitting or lying and playing a musical instrument</td>
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</tr>
<tr>
<td>Sitting or lying and doing artwork or crafts</td>
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</tr>
<tr>
<td>Sitting or lying in a car, bus, or train</td>
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<td></td>
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</tbody>
</table>

HR= Hours
Appendix H

TAS4H Sedentary Strategies Worksheet
The purpose of the Take a STAND 4 Health program is to help you reduce your sedentary time throughout the day by both prompting you and helping you create new habits focused around standing more during the day. We first looked at your level of sedentary behavior and where you are most sedentary.

The top 3 locations/times that you are sedentary are:

1. __________________________________________________________
2. __________________________________________________________
3. __________________________________________________________

Now we will talk about activities that you normally do sitting that you could instead do standing or moving, as well as some strategies for increasing the number of sedentary breaks you take each day. Listed below are strategies that other people have found to be helpful for reducing their sitting time. Read through them and select which ones you think would be the most useful in your day to day!

**Strategies for the home**

- Walk or stand while talking on the phone.
- Stretch out house cleaning time by taking a bit longer- this way you can get healthier while the house gets cleaner!
- Stand during commercials or between episodes (remain standing an extra minute after).
- Pick the show you want to watch before you sit down. Leave the remote next to the TV. Get up and down to change the channels.
- Move around the house more by doing activities such as housework or dancing.
- Instead of just letting the dog outside, either stand with your dog while Fido is outside or walk around the yard with Fido.
- When grocery shopping, walk up and down each isle, even doing it twice to walk longer and to pick up grocery items you may have forgotten the first time.
Instead of letting things pile up at the bottom of the stairs, walk each item upstairs as you notice it needs to go up.

When you are carrying things in from the car (e.g. groceries) take more frequent trips with only one bag at a time.

Walk into the next room to talk to people, rather than calling to them.

Break your computer or TV time during the day with by standing up every 30 minutes.

Stand up between courses during meals or clear the dishes before having dessert.

Play a game with your family to see who can sit down and stand up the most in a minute.

**Strategies for while at work**

Stand to answer the telephone or when making a call.

Hand-deliver a message to a coworker instead of emailing.

Stand up to get the item from the printer the moment you print it rather than waiting till later.

Use restroom on a different floor.

Eat your lunch outside or somewhere other than your desk.

Stand either when you get a new email or stand while reading your email.

Stand during meetings or when chatting with coworkers.

Take a brief walk for a break rather than surfing the net.
Appendix I

TAS4H Intervention “How-To” Guide
Take a STAND 4 Health Website Instructions

1. First, copy and paste the link to the Take a STAND 4 Health site, which is: https://dms.sph.sc.edu/takeastand4health/public/. You will then see the screen below.

![Login Page Screenshot]

2. Enter in your email address and password into the login page, which is pictured below. Also, ensure you click the “remember me” button so that you don’t have to login each time you visit the site.

![Login Page Screenshot]

If you forget your password, you can either email Chelsea or click the “Forgot your Password?” button, which will send an email to the address you signed up with.
3. You will first be taken to the breaks page, which is pictured below. This is where your breaks are scheduled. A description of each part is located below.

Below is an example of a completed day of breaks.
3. You will also receive a report on your weekly reduction of sedentary behavior, which can be viewed after clicking on the “Weekly Report” button, which is outlined below.

4. This will take you to the page pictured below. The first box informs you the days you are receiving feedback on, as well as a breakdown of the percentage of breaks you took, missed, and snoozed during that week. This is done in both word and graph form.
5. The next graph shows you a daily breakdown of your sitting time reduction, which is based on the number of breaks you reported that you took. The green line is at 60 minutes, which is the goal of the program.

6. The next graph (pictured below) shows you a daily breakdown of the following: total breaks, breaks taken, breaks missed, and breaks snoozed each day for the past week.
7. The last graph shows you the time of day you took, missed and snoozed your breaks. This is designed to help you see when prompting is the most effective for you.

8. The last part of the page is to help you determine whether your prompts are at the best times for helping you reach your goals.
How can you use this information to help you reach your goals?
Here are a few steps you can follow:

Step 1: Look at the days you were the most successful in taking your breaks. Ask yourself a couple of questions about these days:
- What days of the week are they? Are they a week day or a weekend day?
- What time of day did you take most of your breaks?
- Are there other days you want to repeat this pattern to get in your targeted breaks?

Answering these questions will help you in finding your “sedentary reduction sweet spot”

Step 2: Now look at the days of the week or the time of day that you most of your breaks were missed or snoozed. Ask yourself a few questions about these days:
- What days of the week are they? Are they a week day or a weekend day?
- What time of day did you take most of your breaks?
- What was it about these days that caused you to not take your scheduled breaks? Was it something you can or can’t change?
  - If it is something you can’t change, then how can you move more of your schedule breaks into those “sedentary reduction sweet spot” times that work for you?
  - If it is something you can change, then what are you going to do differently this upcoming week to make sure you take more of your breaks?

Now that you’ve evaluated this past week, think about this upcoming week. Do you feel like your prompt times line up well with your schedule and you don’t need to revise them? Great! Keep going! However, if you didn’t take a lot of your breaks, this may mean that the prompt was not schedule at the best time for you. Go ahead and revise them now! Here’s the link to fine tune your prompts to reach your goals.

Take me to my breaks!

Take a STAND 4 Health Text Instructions

This is an example of a prompt you will receive to your smartphone after setting up the prompts on the website. It tells you the duration of the break in each prompt.

You will click this link to respond to the prompt with what you will do.
You will then be taken to a screen with 4 options. Click on the option that best describes what you will do at that moment. Then, click submit.

Each day you will receive a feedback text that will include the following information:

- The number of breaks you took versus the number you scheduled
- The amount of sedentary time this reduced
- The percentage that number is of the 60-minute goal
Lastly, you will receive a text that provides you with a link to look at your prompts over the past week.
Appendix J

TAS4H 4-Week Survey
How many prescription medications are you taking for your blood pressure?

[ ] 1
[ ] 2
[ ] 3
[ ] 4
[ ] 5
[ ] 6 or more
[ ] I am not taking any medication for my blood pressure

Thinking about your prescription medication(s) for blood pressure, what is the name of the 1st medication that you are taking?

__________________

Thinking about your prescription medication list, what is the name of the 2nd blood pressure medication that you are taking?

__________________

Thinking about your prescription medication list, what is the name of the 3rd blood pressure medication that you are taking?

__________________

Thinking about your prescription medication list, what is the name of the 4th blood pressure medication that you are taking?

__________________

Thinking about your prescription medication list, what is the name of the 5th blood pressure medication that you are taking?

__________________

Thinking about your prescription medication list, what is the name of the 6th blood pressure medication that you are taking?

__________________

What are the names of your other blood pressure medications that you have not already listed and what do you take them for?

__________________

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the last 7 days. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at school, at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.
Think about all the vigorous activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling? Think about only those physical activities that you did for at least 10 minutes at a time.

Days: XX

How much time in total did you usually spend on one of those days doing vigorous physical activities?

Hours: XXX
Minutes: XXXX

Again, think only about those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

Days: XX

How much time in total did you usually spend on one of those days doing moderate physical activities?

Hours: XXX
Minutes: XXXX

During the last 7 days, on how many days did you walk for at least 10 minutes at a time? This includes walking at work and at home, walking to travel from place to place, and any other walking that you did solely for recreation, sport, exercise or leisure.

Days: XX

How much time in total did you usually spend walking on one of those days?

Hours: XXX
Minutes: XXXX

The last question is about the time you spent sitting on weekdays while at work, at home, while doing course work and during leisure time. This includes time spent
sitting at a desk, visiting friends, reading traveling on a bus or sitting or lying down to watch television. During the last 7 days, how much time in total did you usually spend sitting on a week day?

Hours: XXX
Minutes: XXXX

Please answer the following questions about your sedentary behavior (time you spend sitting) to the best of your ability.

On a typical WEEK DAY in the past week, how much time do you spend (from the time you wake up until you go to bed) SITTING OR LYING while doing the following activities?

<table>
<thead>
<tr>
<th>Activity</th>
<th>None</th>
<th>15 min or less</th>
<th>30 min</th>
<th>1 HR</th>
<th>2 HR</th>
<th>3 HR</th>
<th>4 HR</th>
<th>5 HR</th>
<th>6+ HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting or lying and watching television (including DVDs) on a TV, smartphone, or tablet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying and playing computer, video, or smartphone/tablet games</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying and listening to music on the radio, a MP3 player, or iPod</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying and talking or texting on the phone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying and working on the computer or doing paperwork</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying and reading a book, magazine, or tablet/kindle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying and playing a musical instrument</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying and doing artwork or crafts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying in a car, bus, or train</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HR= Hours

On a typical WEEKEND Day in the past WEEK, how much time do you spend (from the time you wake up until you go to bed) SITTING or LYING while doing the following activities?

<p>| Sitting or lying and watching television (including DVDS) on a TV, smartphone, or tablet |  |  |  |  |  |  |  |  |
| Sitting or lying and playing computer, video, or smartphone/tablet games |  |  |  |  |  |  |  |  |
| Sitting or lying and listening to music on the radio, a MP3 player, or iPod |  |  |  |  |  |  |  |  |
| Sitting or lying and talking or texting on the phone |  |  |  |  |  |  |  |  |
| Sitting or lying and working on the computer or doing paperwork |  |  |  |  |  |  |  |  |
| Sitting or lying and reading a book, magazine, or tablet/kindle |  |  |  |  |  |  |  |  |</p>
<table>
<thead>
<tr>
<th>Sitting or lying and playing a musical instrument</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting or lying and doing artwork or crafts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sitting or lying in a car, bus, or train</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HR= Hours

**Treatment Satisfaction**

The purpose of these questions is to help us design a better program for the future. So, please be as honest as possible in your evaluation of your experience. We appreciate your feedback and efforts to help us improve the program.

Please indicate your level of agreement with the following statements.

1. **The Take a STAND 4 Health website was user friendly.**
   - 1 Strongly Disagree
   - 2 Somewhat Agree
   - 4 Strongly Agree

2. **The Take a STAND 4 Health texts were easy to use.**
   - 1 Strongly Disagree
   - 3 Somewhat Agree
   - 5 Strongly Agree

3. **I liked receiving texts as a reminder to reduce my sedentary time.**
   - 1 Strongly Disagree
   - 3 Somewhat Agree
   - 5 Strongly Agree

4. **I feel like the texts were helpful in reducing my sedentary time.**
   - 1 Strongly Disagree
   - 3 Somewhat Agree
   - 5 Strongly Agree

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5. I found the feedback provided by the program easy to understand.
   1 2 3 4 5
   Strongly Disagree Somewhat Agree Strongly Agree

6. I felt like the program goal of reducing my sedentary time by 60 minutes per day was possible.
   1 2 3 4 5
   Strongly Disagree Somewhat Agree Strongly Agree

7. I found myself reducing my sedentary time even when I wasn’t prompted.
   1 2 3 4 5
   Strongly Disagree Somewhat Agree Strongly Agree

8. I found myself thinking about ways to reduce my sedentary behavior throughout the day.
   1 2 3 4 5
   Strongly Disagree Somewhat Agree Strongly Agree

9. I feel like the prompts helped me reduce my sitting time.
   1 2 3 4 5
   Strongly Disagree Somewhat Agree Strongly Agree

10. I learned a lot about sedentary behavior and my health during the Take a STAND 4 Health program.
    1 2 3 4 5
    Strongly Disagree Somewhat Agree Strongly Agree

11. I would recommend the Take a STAND 4 Health program to a friend or family member.
    1 2 3 4 5
    Strongly Disagree Somewhat Agree Strongly Agree

12. The perfect number of coaching calls for me during an intervention like Take a STAND 4 Health would be:
    1. None/zero
    2. 1
    3. 2
    4. 3
    5. 4
    6. 5 or more
       a. If 5 or more, how many:
13. The perfect length of time of the program like Take a STAND 4 Health for me would be:
   1. 2 weeks or less
   2. 2-4 weeks
   3. 4-6 weeks
   4. 6-8 weeks
   5. 8 weeks or more
      a. If 8 weeks or more, how many:

14. The ideal number of texts/prompts for me would be:
   1. 4 or less per day
   2. 4-8 per day
   3. 8-12 per day
   4. 12-16 per day
   5. 16 or more per day
      a. If 16 or more, how many:

15. The best time for me to receive my daily feedback text would be:
   1. In the morning
   2. In the afternoon
   3. In the evening
   4. No preference
   5. Other
      a. If other, when:

16. The ideal sedentary behavior reduction goal for me would be:
    a. ____________ minutes

Which of the following tools did you feel was the MOST effective for reducing your sedentary time?

- Problem-solving phone calls with my Coach
- Prompting texts
- Feedback on the website
- Choosing sedentary reduction strategies with my coach
- Feedback graph at baseline

Which of the following tools did you feel was the LEAST effective for reducing your sedentary time?

- Problem-solving phone calls with my Coach
- Prompting texts
- Feedback on the website
- Choosing sedentary reduction strategies with my coach
- Feedback graph at baseline
Have you made any changes to help support reducing your sedentary behavior?

- No
- Yes
  o If yes, what changes have you made?
    ▪ I restructured my environment (i.e. I moved my couch to make it easier to stand)
    ▪ I purchased a standing or adjustable desk
    ▪ I downloaded an app because I wanted to continue having prompts for my sedentary time
    ▪ I purchased a wearable such as a Fitbit or Apple watch
    ▪ Other
      • Please specify:

Your comments and thoughts about how to improve the Take a STAND 4 Health program are valuable and we take them seriously. Please give some thought to the following questions and tell us your honest opinion.

1. What recommendations would you make for changes in the program to help it be more helpful in reducing someone’s sedentary time?

2. What did you like most about the program?

3. What did you like the least about the program?
Appendix K

Correlation Tables and Parsimonious Model Comparison
## Correlation Matrix for Change in Systolic Blood Pressure and Possible Covariates

<table>
<thead>
<tr>
<th></th>
<th>Change in % Sedentary Time</th>
<th>Baseline Systolic Blood Pressure</th>
<th>Body Mass Index</th>
<th>Age</th>
<th>Physical Activity at 4 Weeks</th>
<th>Hypertension Status</th>
<th>Race</th>
<th>Blood Pressure Medication Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Change in Systolic BP</strong></td>
<td>-0.254</td>
<td>-0.434*</td>
<td>0.370*</td>
<td>0.012</td>
<td>-0.131</td>
<td>0.0714</td>
<td>-0.024</td>
<td>0.257</td>
</tr>
<tr>
<td><strong>Change in % Sedentary Time</strong></td>
<td>1.00</td>
<td>0.226</td>
<td>-0.236</td>
<td>0.212</td>
<td>0.0428</td>
<td>-0.0118</td>
<td>0.139</td>
<td>-0.060</td>
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<tr>
<td><strong>Baseline Systolic Blood Pressure</strong></td>
<td>-</td>
<td>1.00</td>
<td>-0.168</td>
<td>0.312</td>
<td>0.01</td>
<td>-0.038</td>
<td>-0.179</td>
<td>0.041</td>
</tr>
<tr>
<td><strong>Body Mass Index</strong></td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>-0.125</td>
<td>-0.335</td>
<td>-0.204</td>
<td>0.114</td>
<td>0.199</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>0.03</td>
<td>-0.46*</td>
<td>-</td>
<td>0.079</td>
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<tr>
<td><strong>Physical Activity at 4 Weeks</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>0.039</td>
<td>-0.075</td>
<td>-0.204</td>
</tr>
</tbody>
</table>

* P <0.05
### Correlation matrix for change in diastolic blood pressure and possible covariates

<table>
<thead>
<tr>
<th></th>
<th>Change in % Sedentary Time</th>
<th>Baseline Diastolic Blood Pressure</th>
<th>Body Mass Index</th>
<th>Age</th>
<th>Physical Activity at 4 Weeks</th>
<th>Hypertension Status</th>
<th>Race</th>
<th>Blood Pressure Medication Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in Diastolic BP</td>
<td>0.013</td>
<td>-0.250</td>
<td>0.360</td>
<td>*</td>
<td>-0.108</td>
<td>-0.026</td>
<td>0.201</td>
<td>-0.022</td>
</tr>
<tr>
<td>Change in % Sedentary Time</td>
<td>1.00</td>
<td>0.05</td>
<td>-</td>
<td>0.236</td>
<td>0.212</td>
<td>0.043</td>
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<tr>
<td>Baseline Diastolic Blood Pressure</td>
<td>-</td>
<td>1.00</td>
<td>0.113</td>
<td>-0.255</td>
<td>-0.38</td>
<td>-0.038</td>
<td>-0.179</td>
<td>0.041</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>-0.125</td>
<td>-0.335</td>
<td>-0.204</td>
<td>0.114</td>
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</tr>
<tr>
<td>Age</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>0.029</td>
<td>-0.46*</td>
<td>-0.415*</td>
<td>0.079</td>
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<tr>
<td>Physical Activity at 4 Weeks</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>1.00</td>
<td>0.039</td>
<td>-0.075</td>
<td>-0.204</td>
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*= p< 0.5

Multiple linear regression results for the parsimonious and full model predicting change in systolic blood pressure
<table>
<thead>
<tr>
<th></th>
<th>Change in % Sedentary Time</th>
<th></th>
<th>Change in Breaks</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parsimonious</td>
<td>Full Model</td>
<td>Parsimonious</td>
<td>Full Model</td>
</tr>
<tr>
<td>Adjusted R²</td>
<td>21.9%</td>
<td>25.0%</td>
<td>Adjusted R²</td>
<td>22.9%</td>
</tr>
<tr>
<td>Intercept</td>
<td>25.71 (22.6)</td>
<td>27.75 (29.4)</td>
<td>Intercept</td>
<td>27.36 (22.4)</td>
</tr>
<tr>
<td>Change in % ST</td>
<td>-0.18 (0.28)</td>
<td>-0.16 (0.29)</td>
<td>Change in Breaks</td>
<td>0.31 (0.34)</td>
</tr>
<tr>
<td>Baseline Systolic Blood Pressure</td>
<td>-0.35 (0.16) *</td>
<td>-0.44 (0.16) *</td>
<td>Baseline Systolic Blood Pressure</td>
<td>-0.38 (0.15) *</td>
</tr>
<tr>
<td>BMI</td>
<td>0.57 (0.32)</td>
<td>0.70 (0.16)</td>
<td>BMI</td>
<td>0.63 (0.31)</td>
</tr>
<tr>
<td>Age</td>
<td>-</td>
<td>0.31 (0.18)</td>
<td>Age</td>
<td>-</td>
</tr>
<tr>
<td>Race</td>
<td>-</td>
<td>-0.59 (5.1)</td>
<td>Race</td>
<td>-</td>
</tr>
<tr>
<td>Hypertension Status</td>
<td>-</td>
<td>8.05 (4.4)</td>
<td>Hypertension Status</td>
<td>-</td>
</tr>
<tr>
<td>Change in Medication</td>
<td>-</td>
<td>7.0 (5.0)</td>
<td>Change in Medication</td>
<td>-</td>
</tr>
<tr>
<td>Physical Activity at 4 Weeks</td>
<td>-</td>
<td>0.04 (0.55)</td>
<td>Physical Activity at 4 Weeks</td>
<td>-</td>
</tr>
</tbody>
</table>

Multiple linear regression results for the parsimonious and full model predicting change in diastolic blood pressure
<table>
<thead>
<tr>
<th></th>
<th>Change in % Sedentary Time</th>
<th>Change in Breaks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Parsimonious</td>
<td>Full Model</td>
</tr>
<tr>
<td><strong>Adjusted R2</strong></td>
<td>15.4%</td>
<td>24.9%</td>
</tr>
<tr>
<td><strong>Intercept</strong></td>
<td>1.08 (11.83)</td>
<td>-10.57 (18.69)</td>
</tr>
<tr>
<td><strong>Change in % ST</strong></td>
<td>0.14 (0.19)</td>
<td>0.29 (0.19)</td>
</tr>
<tr>
<td><strong>Baseline Diastolic Blood Pressure</strong></td>
<td>-0.25 (0.13)</td>
<td>-0.28 (0.13) *</td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td>0.56 (0.22) *</td>
<td>0.74 (0.23) *</td>
</tr>
<tr>
<td><strong>Age</strong></td>
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<td>-0.042 (0.12)</td>
</tr>
<tr>
<td><strong>Race</strong></td>
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</tr>
<tr>
<td><strong>Hypertension Status</strong></td>
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</tr>
<tr>
<td><strong>Change in Medication</strong></td>
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<td>4.29 (3.3)</td>
</tr>
<tr>
<td><strong>Physical Activity at 4 Weeks</strong></td>
<td>-</td>
<td>0.34 (0.36)</td>
</tr>
</tbody>
</table>