VARIABILITY OF SEDENTARY BEHAVIOR THROUGHOUT A SEVEN-DAY MEASUREMENT PERIOD

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BY

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Chapter I

Introduction

In 2007, the consequences of sedentary behavior (SB) were estimated to have accounted for 15% of all healthcare costs [1]. As of 2010, this equates to roughly $150 billion a year [1]. These behaviors are associated with an increased risk of weight gain and obesity [2], the metabolic syndrome [3], diabetes [4], heart disease [5] as well as premature mortality [6]. Even in those who engage in health-enhancing physical activity, increased time spent in SBs are independently associated with the above risks [7]. Therefore, it is important to minimize the amount of time spent in SBs regardless of physical activity levels.

SB can be defined as any activity that requires <1.5 metabolic equivalents (METs). METs are a useful, convenient and standardized way to describe the absolute intensity of an activity [8]. One MET is equivalent to a VO₂ of 3.5 ml·kg⁻¹·min⁻¹, which is generally considered to be resting energy expenditure. Common SBs involve sitting or lying down and can include screen-viewing time, such as watching television or computer usage, time spent commuting/driving and time spent sitting at work. However, when assessing individual behaviors, only a small amount of the overall time spent in SB is accounted for [4]. Using total SB measured for the entire day, instead of measuring a single behavior, provides a better representation of one’s overall SB.
SB can be measured either subjectively or objectively. Subjective measurement of SB includes measures such as self-report surveys, recalling past SB or completing a log of SBs performed throughout a pre-determined measurement period. Although easy to administer and cost-effective, these subjective measures are often a less effective measurement tool and typically involve estimation of time spent in SBs. Underestimation by as many as 2 to 4 hours/day in adults [9] has been observed with self-reporting SB, when compared to objective physical activity monitors. However, when objective methods are used, these biases and the associated underestimations are minimized.

Objective measures can include direct observation and activity monitors. Direct observation involves a researcher monitoring participants and recording every activity they perform. However, this method is very burdensome on the researcher and it is difficult for a researcher to observe a participant for longer than a short time period (typically <12 hours). Similarly, these observations generally have to be performed in a more public setting, potentially excluding those behaviors performed in the household. A less burdensome method to observe SB is with the use of activity monitors. Activity monitors measure movement of the body in various ways. One way this movement is recorded is through the detection of accelerations, done by accelerometers. Accelerometers are small devices that are worn on the wrist, hip or ankle and accelerometers have been shown to agree with direct observation from 87-99% when measuring different types of behavior, such as SB or physical activity [10].

With advances in technology, accelerometers are now able to measure many variables. A uniaxial accelerometer (such as the ActiGraph 7164 and GT1M) measures acceleration in the vertical plane only while a triaxial accelerometer (such as the ActiGraph GT3X and GT3X+)
measures acceleration in the vertical, horizontal and lateral planes. These different axes of measurement can be averaged to provide activity counts or individual axes can be evaluated and compared. An activity count records every time an acceleration of the device occurs beyond the set threshold for the accelerometer. Multiple studies have examined the number of activity counts per minute (cpm) that most appropriately represents SB. Thresholds, defined as cut points have been determined for activity intensities that correspond to given cpm. For SB, researchers have yet to agree whether the original, most commonly used, cut point of <100 cpm is most appropriate. Another cut point used in the SB research is <150 cpm [10, 11] has been shown to be an accurate representation of SB but when compared to <100 cpm, only a 3% difference was found [10].

It is most common for objective measurement of SB to use a 7-day wear period [6, 12-14]. This measurement period can be sub-divided into weekdays and weekend days. However, there are only two studies examining how SB varies over this 7-day period. The only two studies examining variability in SB have found no day-to-day variability in younger and older adults [13, 15]. These two studies found that no difference exists between any days of the week yet other studies have shown that SB is lower on the weekends than on weekdays [6]. However, there has yet to be a clear consensus on whether SB varies between days of the week. These previous studies used relatively small sample sizes and did not assess the influence of variables such as age, gender, body mass index and season of data collection, which have been shown to impact SB [6, 12, 16].

There is a lack of research relative to the variability of SB throughout a 7-day measurement period, and assessing this variability will provide valuable insight into the stability
of the measure as well as the number of necessary days of SB measurement. Similarly, many variables have yet be explored when assessing the variability of SB including gender, age, season of collection, physical activity (i.e. step counts or time in moderate-to-vigorous physical activity) and body mass index (BMI). These variables have the potential to impact SB, and therefore should be measured and analyzed when assessing SB.

**Purpose**

Therefore, the primary purpose of this study was to evaluate the variability of SB throughout a 7-day measurement period and to compare SB between weekdays and weekend days. Second, this study aimed to determine the minimum number of days of SB measurement that is comparable to 7-days of measurement. Secondary to the primary purpose, this study aimed to determine if different demographic variables influence the variability of SB. It was hypothesized that there would be no variability in SB throughout a 7-day measurement period. Similarly, it was hypothesized that there would be no difference in SB between weekday and weekend days. It was also hypothesized that fewer than 7 days of SB measurement will be comparable to the typical 7-day measurement period. Furthermore, demographic variables will not play a role in the variability of SB.

**Significance**

The scope of SB research is expanding and there is a need for studies examining the variability of SB. If variability between days does exist, it is important to know where, within the week, this variability in SB occurs and how this affects the interpretation of SB measured over a 7-day period. Since the variability of SB has only been studied in two small (n=52 and n=46) cohorts of adults [13, 15], there is a need for a study examining a larger cohort with adults
of all ages. Similarly, it is important to know how demographic variables, such as age, gender, body mass index and the season of data collection affect SB throughout the week.

**Definition of Terms**

**Sedentary Behavior** – Any activity requiring <1.5 METs, typically involving sitting or lying down. For the purposes of this study, sedentary behavior was defined as percent of the waking day in sedentary behavior.

**Accelerometer** – A small device that measures movement to assess physical activity and SB.

**Activity Count** – An acceleration that is recorded by a device corresponding to either body movement or changes in gravitational pull [17].

**Counts per Minute (cpm)** – The number and magnitude of accelerations that have occurred within a one-minute timeframe [17].

**Cut point** - A set count per minute that defines a threshold for different activity intensities.
Chapter II

REVIEW OF LITERATURE

Sedentary behaviors (SBs) are defined as any activities requiring <1.5 METs [18], which involve sitting or lying down. These SBs have been linked to many negative cardiovascular and metabolic risk factors and, as a result, lead to over $150 billion in health care costs every year [1]. Over the last 50 years, time spent in SBs has been increasing [19], and as this time in SB continues to increase, it is important for SB to be more thoroughly understood. Increases in SB have been linked to a reduced participation in walking/cycling for transportation, increased use of labor saving devices and increased television viewing and other screen-based activities [20]. As SB continues to account for a greater portion of waking time [19], researchers are attempting to better understand this behavior. According to a nationally representative estimate, Americans spend 55% of their waking time in SBs [12]. While the consequences of this behavior are well known, the variability of SB from day-to-day has not been adequately examined.

Examining the variability of SB over a short period is important for researchers to accurately collect and analyze data. While researchers typically capture a small portion, such as 7 days of an individuals’ lifestyle, it is assumed that these days are representative of the individuals’ lifestyle. Researchers commonly use this 7-day period as this has been shown to be similar to longer periods, such as 21 days [15]. To date, no differences in SB have been found between days throughout a 7-day measurement period [13, 15], in contrast to what has been found for
physical activity [21]. It is important for researchers to understand how this behavior varies to identify whether a participant’s data is valid or if other characteristics of that individual or measurement period affect the measurement of SB.

Consequences of Sedentary Behavior

As research on SB continues to expand, the negative impacts of SB on health are becoming better understood. Large scale, nationally representative studies have given insight into not only how much SB is accrued, but also how this SB influences health [2, 4, 12, 22]. These studies have determined time spent in SB using different methods, some assessing total daily SB while others only investigate time spent in individual SBs, such as time spent watching television. Both the amount of time/day spent in SB and the amount of time spent in individual SBs have been linked to many negative cardiovascular and metabolic outcomes.

One of the landmark studies investigating the harmful effects of SB was the Australian Diabetes, Obesity and Lifestyle (AusDiab) study that began in 1999-2000 [4]. This study examined 11,247 adults (55.1% female, 44.9% male) aged ≥25 years (mean age of 51.5 years) in the Northern Territory of Australia [23]. In addition to providing valuable cross-sectional data about the prevalence of diabetes in a healthy, adult population, benchmark data was established for prospective 5- and 12-year studies investigating type-2 diabetes prevalence, risk factors and associated conditions. A sub-cohort of these participants (n=169) from the AusDiab study wore an ActiGraph model 7164 accelerometer during all waking hours for 7 consecutive days. Of all waking time, 57% was spent in SB (<100 cpm) and this time spent in SB was found to be significantly associated with increased waist circumference and increased clustered metabolic risk score, independent of time spent in moderate to vigorous physical activity. These
associations were presented using standardized regression coefficients of 0.22 (95% CI: 0.09-0.36) for an increased waist circumference and 0.23 (0.08-0.38) for clustered metabolic risk score. Self-report data from the AusDiab study found that men and women who reported the most television viewing had an elevated risk for having an increased waist circumference. This 4.2cm increase in waist circumference was 2.62 and 4.22 times higher in men (>2.57 hours) and women (>2.14 hours) respectively, compared to men and women who reported the least television viewing (<0.93 hours and <0.71 hours respectively). Furthermore, women who self-reported the most television viewing had a 2.53 times greater risk of having a systolic blood pressure of >140 mmHg, compared to those who reported the least television viewing. Other small, yet significant, regression coefficients were established between television viewing and 2-hour plasma glucose in men and women as well as fasting plasma glucose, triglycerides and high density lipoprotein (HDL) cholesterol in women.

A major strength of the AusDiab study was the large sample size, utilizing greater than 11,000 adults. However, the methods used to stratify eligible participants to create a nationally representative data set failed to account for men and women who lived in rural or indigenous areas and those areas that were predominantly elderly. While the use of simple subjective measures of SB, such as self-reported television viewing time, eased data collection, it failed to provide a strong representation of daily time spent in SB. While accelerometry was used to correct this issue, it was only used on a small (n=169) sub-cohort of AusDiab participants. The AusDiab study was able to provide valuable insight into the prevalence of diabetes and the negative consequences of time spent in SB.
The National Institutes of Health-American Association of Retired People (NIH-AARP) Diet and Health Study examined 240,819 adults, aged 50-71 years and reported being free of diagnosed cancer, heart disease, stroke, emphysema or poor health. Using questionnaires, both initially and after a mean follow-up of 8.5 years, adults’ television-viewing time, overall sitting time, and moderate to vigorous physical activity were assessed. In those who reported the most television viewing (>7 hours/day), a 1.61 times greater risk of all cause mortality (95% CI: 1.46, 1.76), a 1.85 times greater risk of cardiovascular mortality (CI: 1.56, 2.20) and a 1.22 fold greater risk of cancer mortality (CI: 1.06, 1.40) were found compared to those who reported the least television viewing (<1 hour/day). Even among those who reported greater than 7 hours/week of moderate to vigorous physical activity, significant hazard ratios remained between television viewing and all-cause mortality (1.47; CI: 1.20, 1.79) as well as cardiovascular mortality (2.00; CI: 1.33, 3.00) [22].

Strengths of the NIH-AARP study include the very large sample size, including over a quarter of a million individuals in the United States. The use of a prospective design that involved an 8.5-year long follow-up allowed for the development of strong relationships between SB and mortality. However, self-report measures were used to obtain SB information and can lead to error in measurement. Furthermore, these results are mostly generalizable to those aged 50-71 years who are free of diagnosed heart disease, cancer, emphysema or of self-reported poor health.

The Nurses’ Health Study, conducted from 1992 to 1998, examined 50,277 and 68,497 women for obesity and diabetes analysis, respectively. These women, aged 30-55, were registered nurses from 11 different states, had a body mass index of <30 kg/m² and were free of
diagnosed cardiovascular disease, diabetes or cancer. Television-viewing and overall sitting times were assessed at baseline via interview using standardized questions and answers. The questions and answers used had been validated previously but were phrased similarly to those that had been validated and used previously [24]. After follow-up, it was found that each 2 hour/day increment in television-viewing time was associated with 23% and 14% increases in risk of obesity and diabetes, respectively. Similarly, for every 2 hour/day increment in time spent sitting at work, 5% and 7% increases in risk of obesity and diabetes were observed. Therefore, increased surrogate SBs are associated with an increased risk of both obesity and diabetes [2].

The very large sample size added strength to this study and the sample was collected from 11 states throughout the United States, including both coasts and the north and south borders as well. However, the participants used were all medical professionals in a limited age-range, thus limiting generalizability of the results. The measures used to collect SB data were not validated and subjective measures often underestimate total SB throughout the day, when compared to referent measures [9] therefore reducing the strength of the results. Regardless, the Nurses’ Health Study was able to provide valuable insight into television viewing and other time spent in SB and their associations with obesity and diabetes in these medical professionals.

Negative consequences of SB have been clearly established in multiple large-scale studies. As evidence for SB’s harmful effects on both cardiovascular and metabolic disease, its potential to become an established risk factor is growing. Currently, many models exist for determining disease risk, such as the risk stratification system presented by the American College of Sports Medicine (ACSM) [8]. However, the ACSM model may be an incomplete assessment, as it does not include SB.
Sedentary Behavior: A New Risk Factor

The ACSM recognizes physical inactivity (<30 minutes of moderate intensity physical activity on at least 3 days of the week) as a risk factor for cardiovascular disease [8]. However, physical inactivity and SB are not interchangeable, as SB is defined as 1-1.5 METs and not a lack of moderate-vigorous intensity physical activity. These 2 classifications are distinct and should be treated as such. While current PA guidelines recommend minimizing the amount of time spent in SB [25], no specific recommendations exist for limiting how much time should be spent in SB. Furthermore, even in those who are physically active and achieving the recommended 150 minutes/week of moderate, or 75 minutes/week of vigorous [8], the detrimental effects of increased SB still exist [4, 7, 22]. As research continues to demonstrate negative outcomes associated with increased SB, a call for SB to be assessed as an independent risk factor for cardiovascular and metabolic disease grows.

A sub-cohort of 8,357 adults (45% men, 55% women) aged >35 years from the AusDiab study were evaluated via self-reported television viewing time. Time spent watching television was positively associated with elevated fasting plasma glucose and 2-hour plasma glucose and these associations were stronger in women. For each 1 hour/day increase in television viewing time, fasting plasma glucose increased by 0.02 mmol/L (p=0.04) in men and by 0.04 mmol/L (p=0.001) in women. [26]. Similarly, a sub-cohort of 4,064 adults aged ≥25 years (50% men, 50% women), who were sufficiently physically active (≥150 minutes/week of moderate to vigorous physical activity), was used to assess the associations between television viewing time with multiple cardiovascular and metabolic variables. In those considered active, unfavorable dose-response relationships between television viewing time and waist circumference, systolic blood
pressure and 2-hour plasma glucose were observed in both men and women. Furthermore, fasting plasma glucose, triglycerides and HDL cholesterol were found to be negatively associated with television viewing time in women [7].

Similar results were found in 2011, when Bankoski and colleagues examined data from the 2003-2006 National Health and Nutrition Examination Survey (NHANES) [27]. This analysis examined daily SB via accelerometry, percentage of time in SB/day as well as sedentary breaks and their associations with the metabolic syndrome and its individual risk factors. Sedentary breaks, or any interruption in SB, commonly defined as activity ≥100 cpm, have been shown to be associated with a decreased metabolic risk [28]. On average, individuals with the metabolic syndrome, or a group of risk factors associated with an increased risk for heart disease and other health problems, such as diabetes or stroke, averaged 26 minutes more of SB compared to their healthy counterparts. An association between daily SB and the metabolic syndrome was found, even when correcting for age, smoking, body mass index, diabetes, cardiovascular disease, physical activity [27].

SB continues to be independently linked to multiple disease etiologies and its importance as a cardiovascular and/or metabolic risk factor is growing. Large-scale, representative studies such as the NHANES and AusDiab have and continue to provide a strong foundation for future research to continue examining SB and provide potential to promote not only SB as a risk factor, but to provide limitations for the amount of SB or specific reductions in SB.

**Measurement of Sedentary Behavior**

Sedentary behavior has been measured nationally since the 1960’s in the United States [19], however, the methods of measuring this behavior have changed drastically. In the 1960’s,
SB was measured solely via self-completion logs or surveys. However, these measures struggle to account for all SB accrued throughout the day due to assessment of only surrogate behaviors as well as recall bias and social desirability affecting the participants’ responses. Advances in technology over the last 15 years have led to the development of more sophisticated activity monitors, such as pedometers and accelerometers [14]. These newer measures provide valid and reliable means for measuring SB continuously throughout a given measurement period [10, 29].

Subjective Sedentary Behavior Assessments

Subjective measurement of SB includes measures typically recorded via self-completion, a face-to-face interview or a telephone interview. Self-completion measures can include recording SB in a log or completing a questionnaire regarding SB and these self-completion methods are simple to administer making them commonly utilized. Face-to-face interviews and telephone interviews involve a participant recalling past behavior, typically ranging from 24 hours to a week. These measures often assess SB using surrogate measures, such as television viewing time, passive transportation or time spent sitting at work or home [4-6, 19].

While measures of subjective surveys for SB have shown good test-retest reliability, they often fail to provide strong relationships with referent measures, such as accelerometry or direct observation [24]. Self-recall of SB has been shown to underestimate SB by as many as 2 to 4 hours/day in adults [9], when compared to an accelerometer. Objective analysis of over 10,000 individuals’ physical activity and SB found that anywhere from 7.7-7.9 hours/day was spent in SBs [12, 30], meaning the 2 to 4 hours/day of underestimation would lead to ~25-50% of SB/day unaccounted. In research using SB reduction interventions, the sensitivity of subjective measures has been shown to be lacking as well. In a study of overweight and obese adults, an
ActivPAL accelerometer and two SB questionnaires were used to assess SB initially and during follow-up. The accelerometer detected a significant 4.3% change (p<0.05) from baseline to follow-up while neither questionnaire was able to detect a significant difference [6].

Subjective measures, such as self-report surveys and activity diaries, are also prone to recall bias and social desirability. Recall bias is defined as error caused by differences in the process of recalling past events [31] and social desirability involves the participant incorrectly reporting activity in order to provide what he or she believes to be more favorable answers [32]. This desirability has been shown to be negatively associated with self-reporting SB [33]. These biases contribute to the general underestimation and affect the validity of SB measurement. However, objective methods such as accelerometry have been shown to measure SB similar to reference measures, provide accurate assessments of SB throughout the day.

**Objective Sedentary Behavior Assessments**

Due to the inherent limitations of subjective measurements of SB, reliable objective measures have been developed. These objective measures include direct observation and a variety of activity monitors. Although direct observation has been shown to be a valid measure of SB and is often considered the criterion method for SB assessment [11], it is burdensome on both the researcher and the participant. It is also difficult to observe a participant for longer than a short time period (typically <6 hours) and observations are commonly performed in a public setting, often failing to include household SB or other SB performed in a free-living environment due to privacy issues. Similarly, these measures incur a large expense, as direct observation requires many hours of labor to obtain data. Because of these reasons, activity monitors that provide SB measurements are a commonly used assessment tool.
Activity monitors examine behavior continuously throughout the day and can provide multiple SB variables including energy expenditure, time in specific activity intensity levels and some can provide body position (i.e. supine, sitting and standing). More extensive monitors, such as the Intelligent Device for Energy Expenditure and Physical Activity (IDEEA), consist of a monitor and multiple sensors taped to various parts of the body and measure body position as well as gait positions[29]. Some monitors use an armband that measures skin temperature, and therefore heat flux from the body, in addition to motion, giving an accurate measure of energy expenditure throughout the day [34]. A more practical form of activity monitors is the accelerometer, which is a small device, typically worn on the waist or wrist that measures motion throughout the day.

**Accelerometry**

Accelerometers are small devices that monitor physical activity and SB. These devices identify accelerations associated with movement, allowing for the detection of both activity and a lack thereof. These accelerations are measured based on the force of gravity on the device [35]. Older models of accelerometers, i.e. the ActiGraph GT1M, record only vertical accelerations and are considered uniaxial. Newer models, such as the ActiGraph GT3X and the GT3X+, record accelerations in 3 different planes (vertical, antero-posterior and medio-lateral) directions and are considered triaxial. These accelerations are recorded many times every second, giving a sampling rate commonly between 10 and 100 Hz, depending on the model and settings of the accelerometer. Over a certain period of time (typically ≤60 seconds), or epoch, the accelerations are summed. Researchers typically report activity counts per minute (cpm), which is a measure of the number and magnitude of accelerations that have occurred within a one-minute timeframe.
These activity counts can then be translated into a given activity intensity, using ranges based upon how many cpm are recorded by the device.

**Activity Counts and Cut Points**

Intensity of activity is commonly defined as light, moderate or vigorous physical activity [14, 36] where as a lack thereof constitutes SB. In 1998, Freedson et al. determined cut points for SB and exercise intensities that have been commonly used in physical activity and SB research. Using VO$_2$ as a reference, accelerometer activity counts were divided into ranges corresponding to different activity intensities. Relative to SB, it was determined non-empirically that activity amounting to <100 cpm would be considered sedentary [14]. Even though this cut point was not derived from corresponding metabolic values, as is the case in other activity intensity cut points, it is the most commonly used cut point. A small validation study of 19 adults (10 females and 9 males, average age of 40.1 years) was performed comparing the ActiGraph 7164 (<100 cpm) and the Intelligent Device for Energy Expenditure and Activity (IDEEA) monitor, which identifies SB positions with 98% accuracy [37]. These adults wore the monitors for 2 days, and SB was recorded at 8.64 hours/day and 8.53 hours/day (p=0.82) for the ActiGraph and IDEEA, respectively [12]. As this study was used to validate the use of the <100 cpm cut point for the 2003-2004 NHANES data analysis, the use of a greater sample size would have been beneficial. Similarly, the NHANES data analysis included children, adolescents and adults of all ages while this study only presented the mean age of 40 years. However, comparing the ActiGraph 7164 accelerometer to a near gold standard measure provides valuable feedback regarding the accuracy of the commonly used <100 cpm cut point.
Other cut points that have been utilized for SB include <50 cpm [15] and <150 cpm [11]. In a cohort of 36 healthy, college-aged adults (aged 23.0 ± 3.7 years) with a BMI between 19.7 and 39.1 kg/m² performed testing in a laboratory setting. Two ActiGraph accelerometers (the GT1M and the GT3X+), using both <100 and <150 cpm as cut points for SB, a Stepwatch, and direct observation were compared. Multiple SBs were assessed including lying, sitting and watching television as well as sitting while using the computer. When identifying minutes spent in SB, all 3 monitors identified greater than 80% of activities correctly. When <150 cpm was compared to <100 cpm using the GT3X+ accelerometer, only a very small difference (<3%) was found [10]. A major drawback to this study was the use of a college-aged population who were normal weight (mean BMI of 23.9±3.8 kg/m²), limiting its applicability to those of all ages and body sizes. Comparing multiple activity monitors, as well as multiple cut points, to a gold standard measure (direct observation) allowed for meaningful comparisons within ActiGraph model accelerometers. Similarly, the comparison between cut points not only validated both cut points as viable options for researchers, but also discovered only minimal differences between the two.

Kozey-Keadle et al. (2011) compared the ActiGraph GT3X and the activPAL to direct observation during multiple SBs. A cohort of 20 overweight (mean BMI of 33.7 ±5.7 kg/m²) aged 47 ±11 years was utilized. Participants wore the activity monitors and underwent direct observation for a 6-hour period both before and after an intervention, attempting to reduce time spent in SB. During the 6 hours, participants were observed mostly during working hours and all activities were recorded in conjunction with the activity monitors. The ActiGraph GT3X was found to underestimate SB, <100 cpm, by 4.9% and was not able to detect changes in SB before and after the intervention that were observed with direct observation. While underestimation was
observed when objectively measuring SB, this measure provides a much more accurate representation of daily SB, when compared to subjective measures with greater underestimations of 25-50%. When comparing the cut point of <150 cpm to <100 cpm, a 3.1% difference was found between the 2 cut points. A major limitation of this study was the measurement of SB in a workplace, as only a portion of the day is spent in the workplace. Similarly, these middle aged overweight/obese workers limit the generalizability of the study and may not be applicable to those younger or older, who do not work in a conventional office setting or those of normal weight (BMI of <25 kg/m²). However, the 1000+ hours of time spent in direct observation while participants were wearing activity monitors as well as the use of multiple activity monitors and cut points provides a major strength.

Measurement Period

The duration of observation for SB measurement has typically been 7 days. Subjective measures commonly ask participants to recall their past weeks’ behavior [26] while studies utilizing using objective activity monitors ask participants to wear the monitor for a 7-day period [11, 12]. This 7-day measurement period has been used in many large-scale studies such as the NHANES, AusDiab, NIH-AARP and the Nurses’ Health Study [2, 4, 12, 22]. As it remains the most common measurement period, multiple studies have validated the use of 7-days for measuring both physical activity and SB.

A recent study found that a 7-day wear period has been shown to achieve intra-class correlation reliabilities of 0.85-0.90 in the objective measurement of SB [15]. This study used Spearman-Brown prophecy formulae to determine the minimum number of SB measurement days and found that 5 days of SB measurement was considered reliable. Therefore, the
measurement of an entire 7-day period may not be necessary, and the use of fewer days of the
week may suffice. However, this 7-day period can be sub-divided into individual days of the
week, potentially bringing importance to which days specifically are being measured. To date,
no difference between individual days of the week in SB has been established [13, 15], contrary
to physical activity which has been shown to vary between days of the week [38]. However,
when simply comparing weekdays to weekend days, differences in SB were noted in a small
cohort of overweight, office workers [6] and when measuring inactivity (<500 cpm), differences
between weekdays and weekend days with weekdays being more sedentary/inactive than
weekend days [39]. As physical activity guidelines are based on the amount of activity/week [8],
the use of a 7-day measurement period would translate well to assessing adherence to potential
SB recommendations.

*Sedentary Behavior recorded via Accelerometry*

Multiple large-scale studies have given a picture of how much time is spent in SB. The
NHANES data from 2003-2004 found that American adults’ SB accounted for 7.7 hours/day, or
55% of all waking time. This study utilized the ActiGraph 7164 accelerometer for a 7-day period
and examined 6,329 individuals that were considered representative of the United States
population. The most sedentary groups were older adolescents and those aged >60 years, who
spent 63±1% of their waking time/day in SB. It was also found that women were more sedentary
than men before the age of 30, while males aged 60 years or greater were found to be more
sedentary than their female counterparts [12]. More recent data from the NHANES (2005-2006)
found that 7.9 hours/day, or 57% of waking time, were spent in SB [30]. A major strength of the
NHANES was the large sample size that was representative of the United States population.
However, in order to be included in data analysis, only one day of valid measurement (600 minutes of wear time) was required, allowing data from the large sample size of 6,329 individuals.

The AusDiab study found that SB accounted for 57% of all waking time in a sub-cohort of 169 Australian adults [7]. Participants were instructed to wear the accelerometer for 7 consecutive days, however if the accelerometer was worn for a minimum of 600 minutes on 5 days, one of those being a weekend day, the data were considered valid. However, this sub-cohort was generally younger, better educated and had a higher income than the nationally representative dataset. The requirement of additional days when compared to the NHANES, in addition to the inclusion of potential confounding variables, strengthens the results of this study.

As many models of ActiGraph accelerometers have been used in SB research, studies comparing the results of these accelerometers have been performed. Carr & Mahar recruited 36 participants to wear 3 activity monitors, the ActiGraph GT1M, the ActiGraph GT3X+ as well as the Stepwatch, during multiple SBs and compared the outputs to direct observation. This study found that the GT1M and GT3X+ accelerometers correctly coded SB 98.4% and 87% respectively using a cut point of <100 cpm. However, when using a cut point of <150 cpm, the accelerometers correctly coded 99.2% and 90.1% respectively. Regardless of the cut point, both ActiGraph accelerometers and the Stepwatch were all found to be valid measures of SB [10, 11].

**Variability of Sedentary Behavior**

Few studies have examined the day-to-day variability of SB. Studies investigating the variability between days of the week found no variability throughout a 7-day measurement period [13, 15]. Hart et al. (2011) recruited 52 older men and women (aged 69.3 ± 7.4 years)
with an average BMI of 27.0 kg/m². These individuals wore an ActiGraph 7164 accelerometer for 21 days and assessed both SB (<50 cpm) and physical activity. Relative to SB, no differences were found between any days of the week and 4 days of measurement was found to reliably estimate 21 days of measurement. This study collected data for 21 days, allowing for strong comparisons between fewer days and the 21-day criteria. However, this study used an older cohort (aged 69 ±7 years) thus limiting the generalizability to younger populations.

Similar results were found by Hickey et al. (2013) when 46 adults (aged 45 ±16 years) were observed with an activPAL accelerometer for 7 days. Participants, on average, spent 64% of their time in SB and no difference between any days of the week in SB percent/day and compared those with higher sedentary time to those with lower sedentary time. The group with higher sedentary time was found to have a lower day-to-day variability (11±5%) compared to those with lower sedentary time (18±9%). One major limitation of this study was the use of a small sample size, including only 46 adults. The use of the thigh mounted, activPAL accelerometer likely increased the accuracy of the measurement, as the activPAL correctly identifies >99% of sedentary positions, when compared to direct observation [40].

However, other studies have found that weekdays differ from weekend days relative to time spent in SB [6, 39]. Using activPAL and ActiGraph GT3X accelerometers as well as past week recall questionnaires for surrogate SBs; time spent in SB was assessed in overweight office workers for a 7-day period before and after a SB reduction intervention. The activPAL found that participants were significantly less sedentary and that they stood more on weekend days compared to weekdays. SB accounted for 66% of all waking time on weekdays, compared to 63% using the ActiGraph GT3X with a cut point of <100 cpm. This study had a strong within
subjects design and utilized multiple accelerometers and questionnaires to assess SB. However, this study used a small (n=20) cohort of overweight and obese individuals thus limiting the generalizability to normal weight individuals.

A study examining the variability of inactivity (<500 cpm) in 122 healthy adults using a Computer Science Applications (now ActiGraph) accelerometer examined different sources of variance for physical activity/inactivity measurement. The variance in inactivity could be explained by inter-individual differences (35% for men, 31% for women), day of the week (8% and 13%) and intra-individual differences (57% and 55%). In order to achieve a reliability of 0.80, 7 days of physical inactivity measurement were necessary for men and approximately 8 days of measurement were needed for women. On average, an additional 30-45 minutes was spent in inactivity on weekdays, compared to weekend days. Furthermore, Sundays were shown to account for an additional 25 minutes of inactivity, when compared to Saturday [39]. However, one major limitation is the use of physical inactivity, which combines SB and some light intensity activity when using common cut points, such as the Freedson et al. (1998) cut points. Including adults’ aged 18-79 years increased the generalizability of the results; however, the use of healthy adults provides a limitation.

Although some differences in SB and physical inactivity throughout the week have been noted, there is not a clear consensus whether accelerometry measured SB varies throughout a 7-day measurement period. As the 7-day period has been clearly established for physical activity and SB research, understanding this period more thoroughly is crucial for SB research. As SB has the potential for behavior recommendations and emergence as a risk factor, the need for proper measurement and understanding of this behavior is critical. No large cohort study has
examined the variability of SB throughout a 7-day measurement period or investigated the
effects of potentially confounding variables, such as age, gender, BMI or season of data
collection.

**Gender**

Whether gender plays a role in affecting the variability of SB has yet to be examined.
Analysis of the National Health and Nutrition Examination Survey of 2003-2004 found gender
differences in SB. Women were shown to be more sedentary before the age of 30 (55% for
females versus 52% for males), yet this trend reversed after the age of 60 (61% for males versus
58% for females) and remained in those aged 70-85 years (68% for males versus 66% for
females). Men and women were shown to be similarly sedentary between the ages of 30 and 60
[12]. Future research needs to examine whether or not gender influences the reliability of the
measurement of this behavior throughout a measurement period.

**Age**

As adults age, SB has been shown to change in a variety of ways. Analysis from the
2003-2004 NHANES provided SB data by decade and separated by gender. SB has been shown
to be similar among adults aged 20-39 years and from the ages of 30-70 years SB increased
roughly 2 hours/day with the 70-85 year old age group being the most sedentary. This was
confirmed in an older cohort who on average spent 67% (compared to the American adult
average of 55%) of their waking day in SB. This study of older adults also found that SB tended
to be lower on weekdays than on weekend days [41], which is in contrast to that seen in younger
adults, where no difference was found between weekend days and weekdays [13]. Therefore, SB
may be more variable in older adults than in younger adults and further research is needed to confirm these findings.

Weight/Body Mass Index

While many relationships exist between SB and an increased body weight, it is unclear whether these effects play in role in determining the variability of SB. Those who are overweight spend more time in SB on both weekend and weekdays, by as much as 10%, when compared to normal weight individuals [6, 12, 13]. Increased SB has been shown to be associated with an increased waist circumference [7], as was clearly established in the AusDiab study. Similarly, chronic SB has been shown to increase the likelihood of one becoming overweight (classified as a BMI of $\geq 25$ kg/m$^2$) [42]. However, the effects of weight/BMI on the variability of SB have yet to be well established.

Season

As the weather changes throughout the year, so do participants’ activity levels [12, 43, 44]. In a 2009 study, 57 healthy women in Nashville, TN wore an accelerometer for 7 days at three separate time points during different seasons within 1 year. SB was shown to be 35 minutes/day higher during winter than in summer or spring and a corresponding decrease in physical activity was also seen during these times [44]. Similarly, a study of adults in the United Kingdom investigated SB during each season of the year and found that SB was significantly higher in winter than in all other seasons [43]. Even though changes in physical activity [16] and SB have been established with seasonal changes, no study has examined how seasonal changes affect the variability of SB throughout the measurement period.
Chapter III

Methodology

As sedentary behavior continues to increase in the United States today [19], it is becoming more important for this behavior to be properly measured and further researched. Assessing this behavior with accelerometry is a newer field and has only been studied the last 15 years. Measurement of this behavior via accelerometry has been shown to be a reliable method [10], yet little research has been done investigating the variability of sedentary behavior throughout a typical measurement period.

Subjects and Procedures

Study Population

Accelerometer data from 956 adults, aged ≥18 years, in 22 studies that took place from 2006-2014 at Ball State University in the Clinical Exercise Physiology Program were accessed for this study. These adults were men and women from various settings in Muncie, Indiana. Of these 956 data files, 212 were excluded due to a lack of demographic information, 4 were eliminated due to errors within the accelerometer files and 28 were excluded due to not meeting minimal wear time criteria (3 weekdays and 1 weekend day with 600 minutes/day of wear time), leaving 708 files for analysis. Of these files, 260 were collected from men (57±13 years, body mass index (BMI) 30±6 kg/m\(^2\)) and 448 were collected from women (52±12 years, BMI 29±8 kg/m\(^2\)). Of these 708 data files, 293 met more stringent wear time criteria, with the accelerometer
being worn for a minimum of 600 minutes/day on 7-consecutive days, including those from 99
men (56±14 years, BMI 29±5 kg/m²) and 194 women (52±12 years, BMI 27±7 kg/m²). This 7-
day sub-cohort was defined for the comparison of SB between individual days and determining
the minimum number of SB measurement days.

*Sedentary behavior measurement*

SB was assessed via accelerometry. Specifically, three different models of ActiGraph
(ActiGraph, Fort Walton Beach, FL) accelerometers were used for this study. These models
include the GT1M (n=473), the GT3X (n=127) and the GT3X+ (n=108). Participants were
instructed to wear the accelerometer on the hip during all waking hours, except during water-
based activities, such as swimming or bathing. Initialization of the accelerometer involved input
of the participants’ gender, height, weight and age. SB was defined as any activity accumulating
less than 100 cpm, as this is a commonly used cut point for SB [7, 12, 14].

To determine whether days of the week varied from each other, wear time validation
ensured that the accelerometer was worn for at least 600 minutes per day for 7 consecutive days.
Non-wear periods were defined as ≥60 minutes less than 10 cpm. Data were excluded if it did
not meet the 600 minutes per day on each consecutive day of the measurement week. After wear
time validation, 293 participants’ data remained for comparison of sedentary behavior between
individual days of the week. This 7-day sub-cohort consisted of 99 men (aged 56 ± 14 years,
BMI of 29 ± 5) and 194 women (aged 52 ± 12 years, BMI of 27 ± 7). Two participants were
excluded for having excessive counts per minute when assessing physical activity (>50,000).

*Data Treatment and Statistical Analysis*
Data Treatment

Deidentified participant data was used for this study. These data were stored under participant numbers with all information relating to the individual stored in a separate area. New participant numbers were assigned to all individuals’ accelerometer files. Age was coded by decade and those aged 19 years were included with those aged 20-29 years. Similarly, those aged >70 years were grouped together, as few individuals were aged >80 years. BMI was coded and analyzed by the World Health Organization Body Mass Index Classifications [45]. Season of data collection was defined by the month of the first valid day of wear time. Winter was defined as December, January and February while spring included March, April and May. June, July and August were defined as summer and fall included September, October and November, as these have been used previously for season criteria in physical activity research [44].

Data were processed using ActiLife 6.8.0 (ActiGraph, Fort Walton Beach, FL) software. Data scoring occurred using the Freedson 1998 cut points for sedentary behavior (<100 cpm for sedentary behavior) as well as physical activity. For the uniaxial accelerometer, the GT1M, the cpm was determined using counts from the single axis. For the triaxial accelerometers, the GT3X and the GT3X+, only the vertical axis was used as comparison between multiple axes and the uniaxial GT1M have been shown to be inappropriate [46].

Statistical Analysis

All statistical analyses were conducted using IBM’s Statistical Package for the Social Sciences (SPSS Inc., Chicago, Illinois; version 20.0). To examine the variability of SB throughout a 7-day measurement period, descriptive analyses were first conducted on the 293-accelerometer files that had 7-consecutive days of measurement. However, SB on individual
days violated the assumption of normality, and attempts to correct this violation were unsuccessful, so the untransformed data were used. Demographic variables were assessed using a one-way analysis of variance (ANOVA) comparing each demographic variable (including age, gender, physical activity level, season of data collection and body mass index) to SB across the measurement period. A two-way repeated-measures ANOVA was then conducted comparing the group means of SB for each individual day using gender and day of the week as independent variables. Due to the significant differences in SB between age groups, season of data collection and physical activity level (in minutes of MVPA/week); these variables were included as covariates in the model. Due to violations in sphericity, Greenhouse-geisser p-values were used. In order to determine differences between weekdays and weekend days, the larger cohort of 708 accelerometer files was used. A univariate ANOVA was run comparing average SB comparing weekdays and weekend days by gender and adjusting for age, season of data collection and physical activity level. Statistical significance for all analyses was set to 0.05.

In order to assess whether fewer than 7 days of SB measurement are comparable to 7 days of SB measurement, a stepwise regression was performed using the 293-accelerometer files with 7-consecutive days of measurement. The criterion for this analysis was the dependent variable, SB, and each individual day, or combination of days, was the independent variable. The adjusted $R^2$ was evaluated to determine the amount of variance accounted for by each day or combination of days. The proper combination(s) of days is represented by an $R^2$ value of >0.90, as this has been used when determining the necessary number of days for physical activity measurement [21].
Chapter IV

Research Manuscript

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VARIABILITY OF SEDENTARY BEHAVIOR THROUGHOUT A 7-DAY OBSERVATION PERIOD

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Abstract

PURPOSE: The primary purpose of this study was to evaluate the variability of sedentary behavior (SB) throughout a 7-day measurement period and to compare SB between weekdays and weekend days. Second, this study aimed to determine the minimum number of days of SB measurement that is comparable to 7-days of measurement. Secondary to the primary purpose, this study aimed to determine the role demographic variables play in the variability of SB.

METHODS: Accelerometry data was previously collected in the Clinical Exercise Physiology Program at Ball State University from 708 participants (260 males, aged 57±13 years, BMI = 30±6 kg/m²; 448 females, aged 52±12 years, BMI of 29±8 kg/m²) who wore an accelerometer at least 4 days. To determine if differences exist between individual days, SB data (<100 cpm) from 293 participants (99 males, 194 females) with 7-consecutive days of accelerometry data, were compared using a two-way repeated measures ANOVA. The larger 4-day cohort was used to compare SB on weekdays and weekend days using a univariate ANOVA. To determine the minimum number of SB measurement days compared to the typical 7-day period, a stepwise regression was performed with the 7-day sub-cohort. RESULTS: No differences in SB were found between individual days (p>0.05) when using the 7-day cohort. However, when using the 4-day cohort, weekdays were found to be more sedentary than weekend days (p<0.05). Using the 7-day cohort, 2 weekdays and 2 weekend days of SB measurement were found to be comparable to 7 days of measurement (R² of 0.91). CONCLUSION: No differences in SB were found between individual days of the week, however more time, on average, was observed in weekdays (66%) compared to weekend days (64%). 4 days of SB measurement were found to be comparable to 7, meaning the typical 7-day measurement period may not be necessary.
Introduction

As the physiological consequences of sedentary behavior (SB) are becoming better known, its negative contributions to health care are becoming well established. A 2007 estimate stated that sedentary lifestyles account for 15% of all healthcare costs (1). These costs from SBs are due to the increased risk of weight gain and obesity, the metabolic syndrome, diabetes, heart disease as well as premature mortality (9, 13, 16, 19, 22). SBs can be defined as any activity requiring less than 1.5 metabolic equivalents (METs) and involve sitting or lying including behaviors such as screen-viewing time, time spent commuting and time spent sitting at work or home.

When assessing SB, objective measurements are often preferred due to the potential gross underestimation associated with subjective measurements (17). Accelerometry has been shown to be a valid objective measure of SB in a free living environment (18) and agrees with direct observation, the criterion measure, from 87-99% when measuring different types of SB (6). Accelerometers are often used to determine the intensity of various activities based on the number of counts in a given minute. From these counts per minute (cpm), minimum and maximum values, referred to as cut points; define ranges that represent SB as well as physical activity intensities.

SB is typically measured over a 7-day period, in order to account for all days of the week. While this measurement period has been used consistently in this area of research, little is known about how SB varies throughout that period. Only two studies using small cohorts have examined the variability of SB and have found that no differences exist between days of the week (11, 15). One of these studies measured SB in 52 older adults for 21 days, and found that
no difference exists between individual days of the week when measuring SB with an ActiGraph accelerometer (11). Similar results were found when 46 adults’ (aged 45±16 years) SB was assessed using an activPAL accelerometer (15). While these small studies have failed to show differences between individual days, there is a need to examine the variability of SB using a larger cohort and accounting for demographic variables that have been shown to impact SB. The importance of examining the variability of SB provides a basis for determining the number of days, or which type of days (weekdays versus weekend days) of measurement are necessary for effective measurement of SB.

Therefore, the primary purpose of this study was to evaluate the variability of SB throughout a 7-day measurement period and to compare SB between weekdays and weekend days. Second, this study aimed to determine the minimum number of days of SB measurement that is comparable to 7-days of measurement. Secondary to the primary purpose, this study aimed to determine the role demographic variables play in the variability of SB.

Methods

The Ball State University Institutional Review Board determined this study to be exempt due to the use of deidentified, retrospective data.

Study Population

Accelerometer data from 956 adults, aged ≥18 years, in 22 studies that took place from 2006-2014 at Ball State University in the Clinical Exercise Physiology Program were accessed for this study. These adults were men and women from various settings in Muncie, Indiana. Of these 956 data files, 212 were excluded due to a lack of demographic information, 4 were
eliminated due to errors within the accelerometer files and 28 were excluded due to not meeting minimal wear time criteria (3 weekdays and 1 weekend day with 600 minutes/day of wear time), leaving 708 files for analysis. Of these files, 260 were collected from men (57±13 years, body mass index (BMI) of 30±6 kg/m$^2$) and 448 were collected from women (52±12 years, BMI of 29±8 kg/m$^2$). Of these 708 data files, 293 met more stringent wear time criteria, with the accelerometer being worn for a minimum of 600 minutes/day on 7-consecutive days, including those from 99 men (56±14 years, BMI of 29±5 kg/m$^2$) and 194 women (52±12 years, BMI 27±7 kg/m$^2$). This 7-day sub-cohort was defined for the comparison of SB between individual days and determining the minimum number of SB measurement days.

**Sedentary behavior measurement**

SB was measured using three different models of ActiGraph (ActiGraph, Fort Walton Beach, FL) GT1M (n=473), GT3X (n=127) and GT3X+ (n=108) accelerometers and was determined as any activity accumulating <100 cpm using the vertical axis, as this is a commonly used cut point for SB (10, 14, 20). Accelerometers were initialized using the participants’ height, weight, age and gender. Participants were instructed to wear the accelerometer on the hip during all waking hours, except during water-based activities, such as swimming or bathing.

**Data Treatment**

Deidentified accelerometry data that was labeled using distinct, new participant numbers were used for this study. All identifying participant information relating to the individual was stored in a separate area. Demographic information provided with the accelerometry file included height, weight, age, season of data collection. Age was coded by decade and those <20 years (n=2) were included with those aged 20-29 years. Similarly, those aged >70 years were
grouped together, as only 5 individuals were aged ≥80 years. BMI was coded and analyzed by the World Health Organization Body Mass Index Classifications (7). Season of data collection was defined by the month of the first valid day of wear time. Winter was defined as December, January and February while spring included March, April and May. June, July and August were defined as summer and fall included September, October and November, as these have been used previously for season criteria in physical activity research (5). Physical activity intensity was coded using the Freedson et al. 1998 cut points for uniaxial accelerometry with corresponding ranges for light, moderate, vigorous and very vigorous of 100-1951, 1952-5724, 5725-9498, and ≥9499 cpm, respectively (10). Minutes spent in moderate, vigorous and very vigorous intensities were calculated using these cut points and minutes of moderate-to-vigorous physical activity per week (MVPA/week) were calculated using the following formula, minutes of MVPA/week = moderate + 2*(vigorous + very vigorous). Vigorous and very vigorous minutes were doubled in this equation due to recommendations for physical activity suggesting 150 minutes/week of moderate intensity or 75 minutes/week of vigorous or very vigorous intensity (4).

Data were processed using ActiLife 6.8.0 (ActiGraph, Fort Walton Beach, FL) software. Data scoring occurred using the Freedson 1998 cut points for sedentary behavior (<100 cpm for sedentary behavior) as well as physical activity. For the uniaxial accelerometer, the GT1M, the cpm were determined using activity from the single, vertical axis. For the triaxial accelerometers, the GT3X and the GT3X+, only the vertical axis was used as comparisons between multiple axes using the vector magnitude and the uniaxial GT1M have been shown to be inappropriate (24).

Statistical Analysis
All statistical analyses were conducted using IBM’s Statistical Package for the Social Sciences (SPSS Inc., Chicago, Illinois; version 20.0). To examine the variability of SB throughout a 7-day measurement period, descriptive analyses were first conducted on the 293-accelerometer files in the 7-day cohort. SB was evenly distributed around the mean. Demographic variables were assessed using independent one-way analysis of variance (ANOVA) tests for each demographic variable comparing it to SB across the 7-day measurement period. A two-way ANOVA compared the group means of the individual days with gender as a between-subjects factor and adjusted for age, season of data collection and physical activity level. A follow-up one-way ANOVA was used to determine where gender differences exist between days. Due to violations in sphericity, Greenhouse-geisser p-values were used for the two-way ANOVA.

In order to determine differences between weekdays and weekend days, the 4-day cohort of 708 accelerometer files was used. A univariate ANOVA was run comparing mean SB for weekdays and weekend days with gender as a between-subjects factor and accounting for age, season of data collection and physical activity level, which were found to be different across weekdays and weekend days. No differences were noted in other demographic variables between weekdays and weekend days. Statistical significance for all analyses was set to 0.05.

In order to assess whether fewer days of SB measurement are comparable to 7 days of SB measurement, a stepwise regression was performed using the 293-accelerometer files in the 7-day sub-cohort. The dependent variable for this analysis was mean SB throughout the week, and SB for each individual day was the independent variable. For this model, regressions were performed for each individual day as well as for combinations of days. These combinations started as 1 day and additional days were added in succession to determine which combination of
days accounted for enough of the variance to be considered comparable to 7 days. The adjusted 
$R^2$ was evaluated to determine the amount of variance accounted for by each day or combination 
of days. The proper combination(s) of days is represented by an $R^2$ value of >0.90, as this has 
been used when determining the necessary number of days for physical activity measurement 
(26).

**Results**

Table 4.1 provides general demographic information of the 7-day cohort. No differences 
in SB were found between individual days of the week (p=0.32, Figure 4.1). When using the 
larger 4-day cohort, differences between weekdays and weekend days were found (p=0.00, effect 
size = 0.03) with 66±11% of time on weekdays and 64±12% of waking time on weekend days 
being spent in SB.

When exploring the influence of demographic variables on the variability of SB, a 
significant interaction was found between gender and individual days of the week (p=0.01, effect 
size = 0.06) showing that men spent more time in SBs on both Saturdays and Sundays than 
women (Table 4.3). Furthermore, men spent 4% more of their waking time in SBs on weekend 
days and 1% more on weekdays than women who spent 3% less time in SB on their weekend 
days. While gender differences existed between individual days of the week, no other 
interactions between day of the week and physical activity level, BMI, age or season of data 
collection were found. Although these variables did not influence the variability of SB, 
differences in SB were noted with season of data collection, age and physical activity level while 
no differences in SB were noted between BMI classifications (Figure 4.2).
When examining mean SB and season of data collection, differences between winter and spring were found, while no other seasons were found to be different. Participants spent 4% less of their waking time in SB during the spring than in winter (Table 4.4). When examining the amount of time spent in SB by age group, those aged >70 years were found to be more sedentary than younger individuals were (Table 4.5). Lastly, those who were physically active (>150 minutes/week of MVPA) spent significantly less time in SB on every day of the week (Table 4.6).

When determining the minimum number of SB measurement days found to be comparable to a 7-day measurement period, it was found that any weekday would provide an $R^2$ value of 0.56-0.58 while any weekend day would provide an $R^2$ of 0.40-0.45 (Table 4.2). The best predictor was Friday, accounting for 58% of the variance while Saturday provided the least valuable prediction of overall SB accounting for 40% of the variance. When combining two weekdays the $R^2$ value increased to 0.73-0.76 and adding a third weekday, the $R^2$ increased to between 0.819-0.821. However, when combining two weekdays and a weekend day, $R^2$ values of 0.836-0.869 were found. Including all 5 weekdays revealed an $R^2$ of 0.897. However, fewer days were needed to achieve 90% of the variance when using 2 weekdays and 2 weekend days, providing an $R^2$ of 0.91.

**Discussion**

**Variability of Sedentary Behavior**

No differences in SB between individual days of the week were found which corresponds with previous research findings showing no day-to-day variability between individual days in SB throughout a 7-day measurement period (11, 15). With the large sample size used in this study,
this study provides strong evidence supporting the stability of sedentary behavior throughout a 7-day period. Due to the stability of this behavior, this provides a basis for establishing less than a one-week measurement as being comparable to a 7-day period. The potential to monitor participants for a shorter period would ease burden on both the researcher and the participant.

The present cohort was found to be more sedentary than nationally representative estimates of SB (64% versus 55% of waking time spent in SB), which is significant because the variability of SB was shown to be less in individuals with higher amounts of SB in a study examining the variability of SB throughout a 7-day measurement period (15). While this study did not find any differences between days of the week in SB, they did find that those who were in the >50th percentile for time spent in SB had lower coefficients of variation than those in the <50th percentile. Therefore, the amount of time spent in SB by the present cohort (64% of waking time, on average) could play a role in the stability of SB found in the present study.

Differences in SB between weekdays and weekend days, on average, were found in the present study. However, due to the minimal effect size it is unlikely that these results are meaningful with <1% of the variance being accounted for by the weekday/weekend day groupings, it is probable the differences between days were not large enough to elicit a meaningful difference. This is similar to what was found in a cohort of 46 adults (gender not reported) aged 45±16 years who wore an activPAL accelerometer for 7 days and spent 64% of their waking time in SB and no differences between weekdays and weekend days were found (15). However, a study of overweight, non-exercising, office workers (n=14) aged 20-65 years noted differences in SB between weekdays and weekend days of 3% (19). The present cohort
was also overweight on average (BMI 28±5 kg/m^2), but was physically active with 32 minutes of MVPA/day, which is in contrast to the previous study.

Similar results were found between the present study and the previous study of overweight office workers with (2% and 3% respectively) differences in SB noted between weekdays and weekend days. However, the minimal effect size in the present size might provide evidence that these small differences may not be meaningful in either study. It has yet to be established the amount of SB change necessary to increase or reduce the risk of unfavorable health outcomes, therefore interpretation of these small differences is difficult. Understanding the potential risk associated with an additional 2-3% of SB/day could influence the amount of time spent in SB. Establishment of a dose-response relationship between SB and health outcomes would allow meaningful differences to be based on the amount of reduction necessary to elicit a response. Current investigations have only examined associations between SB and negative health outcomes, such as weight gain (16), cardiovascular disease (22), diabetes (12) as well as premature mortality (23). While the associations between SB and these outcomes are well established, the application of these results specific to changes in SB has yet to be established. The stability of SB throughout the between weekdays and weekend days provides evidence that broader groupings of weekdays and weekend days may be appropriate. Although stability exists within these groupings, the small differences that exist between the groupings may provide insight for future SB interventions or recommendations.

*The Number of Days Necessary to Measure Sedentary Behavior*

When determining the number of necessary measurement days, 2 weekdays and 2 weekend days were shown to be comparable (R^2 >0.90) to the 7-day measurement period. Only
one study examining 50 adults >55 years old explored the number of days necessary to measure SB (11). This study found no differences between any days of the week, and determined that any 5 days of SB measurement accurately represented 21 days of measurement, using Spearman-Brown prophecy formulae. While this study used a 21-day measurement period for the purposes of estimating physical activity and SB, the authors concluded that a 7-day measurement period produced similar results, using intra-class correlations, and was therefore appropriate when measuring physical activity or SB. Although the measurement periods are different, the similarities noted in the previous study between 7-day periods and 21-day periods allows for comparison of these two studies.

The present study found that only 2 weekdays and 2 weekend days of SB measurement were comparable to the 7 days of measurement. Furthermore, weekdays were shown to be stronger predictors than weekdays (Table 4.2) likely due to the stability of SB throughout weekdays while differences were noted on weekend days between genders and within females. Furthermore, this study utilized 293 adults (99 men and 194 women) included adults aged 19-55 years compared to the 52 older adults used in the previous study. The 4 days found to be comparable to 7 days in this study can provide minimal wear-time requirements when assessing SB for a 7-day period in the future.

**Variability of Sedentary Behavior by Gender**

In the 7-day sub-cohort, gender differences in SB were found for Saturdays and Sundays. No other study has yet examined the differences between genders on individual days of the week. While previous research has noted gender differences for the average amount of time spent in SB for a measurement period, this study provides valuable insight into gender differences within the
measurement period. NHANES data using uniaxial accelerometry from 2003-2004 found gender differences in average SB with men aged <30 years spending 3% less time in SBs than women and women aged >60 years spent 2% more time in SB than men with those aged 30-60 years being similarly sedentary. However, the NHANES study presented SB as an average for all the individuals’ days, instead of presenting it by individual days of the week as the current study did. The NHANES study was able to establish nationally representative gender differences in SB while the present study was able to identify specifically, within the week, where these differences in SB exist.

Interestingly, previous physical activity research has shown that men engage in more physical activity than females (2, 25). The same NHANES data from 2003-2004 was also used to assess physical activity and this uniaxial accelerometry data set found that men spent 35 minutes/day in MVPA while women spent 17 minutes/day in MVPA (25). The present study found that men spent 36 minutes/day in MVPA while women spent 30 minutes/day in MVPA. It is likely these differences in women between studies are due to the nature of the populations studied. While the NHANES presents nationally representative data with only 5% of individuals obtaining the recommended 150 minutes/week of MVPA when only including bouts of ≥10 minutes (4), the current study used a population that was 60% compliant with the 150 minute/week recommendation. While men may participate in more MVPA, it appears they also spent an increased amount of time in SB which was found in the present study as well as in adults aged >60 in the NHANES analysis. With this knowledge of differences in SB and MVPA and the previous research showing unfavorable outcomes associated with SBs regardless of physical activity (3, 8); SB needs to be identified as an individual risk factor.
Variation in Sedentary Behavior with Seasonal Changes

When comparing SB between individual days of the week by season of data collection, no differences in SB were found. However, the increased 4% of time spent in SB in winter, compared to spring, equates to an additional 34 minutes/day of SB while no other seasons were found to be different from each other. This is similar to previous research finding that winter was more sedentary than spring, however winter has been shown previously to be more sedentary than all other seasons (5, 21). However, previous research examined the same individuals at different points throughout the year to assess seasonal variation within participants. The present study examined seasonal variation between participants and assumed that SB was evenly distributed within these groups. Furthermore, data for the present study were collected in the Midwestern United States where large temperature fluctuations between seasons and between similar seasons of different years occur. Therefore, the seasonal differences in SB in the present study may be applicable only to areas with similar climate changes throughout the year.

Although SB was shown to be higher in winter than in spring, on average, season of data collection did not influence SB throughout the 7-day measurement period. Furthermore, the increased amount of time spent in SB noted for winter compared all other seasons have been established in previous research (5, 21), are presented for average SB throughout the measurement period, rather than for a 7-day period. Therefore, it appears that the stability of SB measurement, throughout a 7-day measurement period, is maintained throughout all seasons of the year.

Variability of Sedentary Behavior by Age Group
No day-to-day variability in SB was found when comparing individual days relative to age group. Thus, it appears that age does not play a role in the variability of SB. Even though older adults were found to be more sedentary than their younger counterparts were, no day-to-day variability in SB occurred.

When comparing individual days between age groups, differences were found for Saturdays and Sundays between age groups. On Saturdays, individuals aged >70 years were found to be more sedentary than those aged 30-39 and 50-59 years and those aged >70 years were found to be more sedentary than individuals aged 30-59 years on Sundays. With those aged ≥70 years being more sedentary than those aged 30-59 years on both weekdays and weekend days, these findings are similar to those found in NHANES analyses that found adults aged >70 years were the most sedentary, with time spent in SB beginning to increase around the age of 30 (20). The present age group differences between those aged >70 years and younger adults ranged from 6-13% and these differences are less than those noted in the NHANES study. Individuals aged >70 years were 9-22% more sedentary than younger age groups (20), suggesting that SB was more similar between age groups in the present study. The present study had an uneven proportion of adults in each age group, with ages being evenly distributed around the mean. Individuals aged 40-69 years made up 77% of the present study, while only 14% and 9% of individuals were aged <40 years and ≥ 70 years, respectively. The NHANES study used a multistage probability sampling method in order to obtain a representative sample of United States citizens, and therefore represented each age group appropriately (20).

*Variability of Sedentary Behavior by Physical Activity Compliance*
The 2008 Physical Activity Guidelines for Americans to obtain at least 150 minutes of moderate or 75 minutes of vigorous physical activity per week to obtain health benefits (4). Of the 293 data files in the 7-day sub-cohort, 60%, or 176 participants, met the recommend level of physical activity, averaging 233 minutes/week of MVPA. However, the 2008 guidelines recommended obtaining these 150 minutes through a minimum of 10-minute bouts. However, the present study did not account for bout time and simply used the amount of time spent in these behaviors likely overestimating the amount of time spent in MVPA. Throughout the 7-day measurement period, those who met the recommended level of physical activity had significantly less SB on every day of the week (p<0.05), (Table 4.3). However, this population is much more physically active than what has been previously shown for American adults. NHANES uniaxial accelerometry data from 2003-2004 found that only 5% of adults were obtaining the recommended levels of physical activity in bouts of at least 10 minutes (25), while 60% of the current study population met the recommended levels of physical activity when simply using minutes spent in physical activity.

It appears that physical activity may still influence the amount of time spent in SB despite these behaviors being independently associated with multiple disease processes (12). The current study is the first to examine how physical activity influences SB on a daily basis. Even though those meeting the recommended activity levels spent less time in SB, on average, SB was found to be stable throughout a 7-day measurement period regardless of physical activity (in moderate-to-vigorous minutes/day) level.

*Variability of Sedentary Behavior by Body Mass Index Classification*
BMI was found to have no effect on SB for individual days of the week. While increased time spent in SB has been shown to be associated with an increased waist circumference (13), increased risk of obesity (16) and increased diabetes and the metabolic syndrome (3, 12), BMI had no impact on the day-to-day variability of SB, as no differences were noted between individual days of the week for different BMI classifications. No previous research has investigated how BMI affects the variability of SB and the present study found SB to be stable across all classifications of BMIs. The present study of overweight (BMI of 28±5 kg/m²) adults, on average, found that participants spent 64% of their waking time in SB. However, NHANES data from adults who on average were similarly overweight (BMI of 27±4 kg/m²) suggests that American adults spend only 55% of their time in sedentary behavior (20). Therefore, it appears the present cohort was more sedentary than nationally representative estimates of similar weight individuals. A study examining the variability of SB found that those who spent more time in SB were shown to have less variability day-to-day to their less sedentary counterparts (15). Therefore, the present cohort being more sedentary than national estimates could play a role in the stability of SB noted with the present study.

Strengths and Limitations

Strengths of this study include the use of 7-consecutive days of measurement accounting for every day of the week and the sample size of 293 participants with 2,051 person-days of SB measurement. When comparing weekend days to weekdays, a larger cohort was utilized (n=708) providing 4,246 days (3,143 weekdays and 1,103 weekend days) of SB measurement, amounting to 58,537 person-hours of wear time. The inclusion of potential confounding variables, such as gender, age, BMI, season of data collection and physical activity provided additional strength, as
these variables have been previously associated with different levels of SB. While these variables did not all provide significant differences in SB in the present study, the examination of these variables in the present study provides a basis for exploring these variables in future SB research.

A limitation of the present study was the absence of other demographic variables associated with differences in SB, such as occupation and race. However, the present population was recruited from a community that is 84% White, 11% African-American and 2% Hispanic or Latino, making it likely that the present cohort was predominantly White, thus limiting the generalizability to populations with different races contributing a greater proportion. Of the 7-day cohort used for this study, 60% were physically active (achieving >150 minutes/week of MVPA), likely due to participation in structured exercise programs such as the Adult Physical Fitness Program or Cardiac Rehabilitation. This 60% is much higher compared to other objectively monitored estimates of physical activity in American adults, possibly due to overestimation of MVPA due to not using physical activity bouts of at least 10 minutes. The participants examined were aged 19-90, a large majority (226 out of 293) of adults were aged between 40 and 69 year and this likely under-represented those aged <40 years and >70 years. BMI was not evenly distributed across all classifications, especially in those in specific classifications of obesity. Lastly, previous research in seasonal variation in SB has assessed individuals between different seasons of the year, while the present study examined SB between individuals during different seasons, therefore assuming that individuals across all seasons were similar to each other.

Conclusions
Throughout a 7-day measurement period, no differences exist between days in SB. This study provides strong evidence for the stability of SB measurement over 7 consecutive days and provides a basis for using <7 days of SB measurement. Although no variability exists between individual days of the week, differences exist between weekdays and weekend days, on average, with 2% more time being spent in SB on weekdays than weekend days. However, due to the minimal effect size, it is unlikely these results are meaningful and future research needs to define the extent of necessary change to elicit a difference in health outcomes. This would allow the formation of recommendations for interventions as well as general health guidelines.

When establishing the fewest number of days of SB measurement, <7 days of measurement, specifically any 2 weekdays and the 2 weekend days, were found to be comparable. These 4 days provide potential for minimal wear time criteria when evaluating SB over a 7-day period thus potentially reducing both researcher and subject burden. Furthermore, gender plays a role in this variability, with men spending more time in SB on both Saturdays and Sundays, as well as on weekdays and weekend days, on average, when compared to women. These gender differences, although small, provide valuable information for targeting specific genders’ SB and designing interventions based on what is known. No other demographic variables were found to play a role in the variability of SB in the present study; however, it appears that these variables may still play a role for time spent in SB.
References


### Table 4.1 Characteristics of subjects with 7 valid days of accelerometer data

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male</th>
<th>Female</th>
<th>All Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants, n</td>
<td>99</td>
<td>194</td>
<td>293</td>
</tr>
<tr>
<td>Age, years</td>
<td>55.8(^\d) (14.4)</td>
<td>51.6 (12.4)</td>
<td>53.0 (13.3)</td>
</tr>
<tr>
<td>Weight, lb</td>
<td>195.7(^\d) (35.5)</td>
<td>156.2 (37.6)</td>
<td>169.5 (41.3)</td>
</tr>
<tr>
<td>BMI, kg(\text{m}^{-2})</td>
<td>28.7(^\d) (5.2)</td>
<td>26.8 (6.7)</td>
<td>27.5 (6.3)</td>
</tr>
<tr>
<td>Wear time, min(\text{day}^{-1})</td>
<td>852.5 (66.2)</td>
<td>851.3 (66.0)</td>
<td>851.7 (65.9)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index
*Data are expressed as mean (SD)
\(^\d\) Denotes significant difference between gender
<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>$R^2$</th>
<th>Adjusted R square</th>
<th>Standard error of the estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thurs</td>
<td>0.749</td>
<td>0.562</td>
<td>0.56</td>
<td>0.05</td>
</tr>
<tr>
<td>Thurs, Fri</td>
<td>0.854</td>
<td>0.73</td>
<td>0.728</td>
<td>0.04</td>
</tr>
<tr>
<td>Thurs, Fri, Sat</td>
<td>0.926</td>
<td>0.858</td>
<td>0.857</td>
<td>0.03</td>
</tr>
<tr>
<td>Thurs, Fri, Sat, Sun</td>
<td>0.954</td>
<td>0.91</td>
<td>0.909</td>
<td>0.02</td>
</tr>
<tr>
<td>Thurs, Fri, Sat, Sun, Mon</td>
<td>0.979</td>
<td>0.958</td>
<td>0.957</td>
<td>0.02</td>
</tr>
<tr>
<td>Thurs, Fri, Sat, Sun, Mon, Tues</td>
<td>0.991</td>
<td>0.981</td>
<td>0.981</td>
<td>0.01</td>
</tr>
<tr>
<td>Thurs, Fri, Sat, Sun, Mon, Tues, Wed</td>
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<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
Table 4.3 Sedentary Behavior† by Day of the Week for Gender

<table>
<thead>
<tr>
<th></th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
<th>Saturday</th>
<th>Sunday</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men, n=99</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wear time, min/day</td>
<td>856 (101)</td>
<td>862 (114)</td>
<td>880 (113)</td>
<td>841 (113)</td>
<td>872 (121)</td>
<td>847 (117)</td>
<td>810 (103)</td>
</tr>
<tr>
<td>SB (percent/day)</td>
<td>63.7 (11.0)</td>
<td>64.1 (10.8)</td>
<td>66.2 (9.9)</td>
<td>64.3 (11.3)</td>
<td>65.1 (10.7)</td>
<td>64.6* (10.1)</td>
<td>67.0* (10.5)</td>
</tr>
<tr>
<td><strong>Women, n=194</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wear time, min/day</td>
<td>858 (115)</td>
<td>853 (118)</td>
<td>868 (107)</td>
<td>878 (109)</td>
<td>870 (118)</td>
<td>829 (102)</td>
<td>803 (101)</td>
</tr>
<tr>
<td>SB (percent/day)</td>
<td>64.2 (9.3)</td>
<td>65.6 (9.4)</td>
<td>64.9 (9.6)</td>
<td>65.5 (9.7)</td>
<td>65.3 (9.7)</td>
<td>61.7* (11.1)</td>
<td>62.8* (11.6)</td>
</tr>
</tbody>
</table>

†Presented as mean (SD)
*Denotes significant difference (p<0.05) between sexes for the specific day of the week
Table 4.4 Sedentary Behavior by Season

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants, n</td>
<td>85</td>
<td>31</td>
<td>51</td>
<td>126</td>
</tr>
<tr>
<td>Wear time (min/day)</td>
<td>853.9 (65.9)</td>
<td>844 (56.2)</td>
<td>854.9 (72.0)</td>
<td>850.8 (66.2)</td>
</tr>
<tr>
<td>SB (percent/day)</td>
<td>66.3† (7.4)</td>
<td>62.0† (8.5)</td>
<td>64.1 (6.7)</td>
<td>64.1 (7.3)</td>
</tr>
</tbody>
</table>

* Seasons were divided into 3-month periods. Winter: Dec, Jan, Feb. Spring: Mar, Apr & May. Summer: June, July & Aug. Fall: Sep, Oct, Nov. [44]
† Denotes significant difference between seasons (p<0.05)
Table 4.5 Sedentary Behavior\(^{3}\) per Day by Age Group

<table>
<thead>
<tr>
<th>Participants, n</th>
<th>18-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
<th>60-69</th>
<th>70+</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monday</strong></td>
<td>19</td>
<td>21</td>
<td>67</td>
<td>102</td>
<td>57</td>
<td>27</td>
<td>293</td>
</tr>
<tr>
<td>Monday</td>
<td>60.9 (11.4)</td>
<td>61.3 (10.2)</td>
<td>63.1 (9.4)</td>
<td>64.6 (8.3)</td>
<td>64.1 (12.0)</td>
<td>68.3 (9.6)</td>
<td>64.0 (10.2)</td>
</tr>
<tr>
<td>Tuesday</td>
<td>62.4 (10.9)</td>
<td>65.5 (9.3)</td>
<td>65.4 (8.7)</td>
<td>64.3 (10.5)</td>
<td>64.9 (10.7)</td>
<td>69.2 (7.7)</td>
<td>65.1 (9.6)</td>
</tr>
<tr>
<td>Wednesday</td>
<td>64.1 (8.9)</td>
<td>63.1 (7.0)</td>
<td>63.5 (10.2)</td>
<td>65.9 (9.5)</td>
<td>66.2 (10.2)</td>
<td>68.6 (9.4)</td>
<td>65.4 (9.2)</td>
</tr>
<tr>
<td>Thursday</td>
<td>61.0 (9.6)</td>
<td>63.5 (8.6)</td>
<td>64.9 (9.5)</td>
<td>65.4 (10.0)</td>
<td>65.6 (12.2)</td>
<td>67.6 (10.2)</td>
<td>65.1 (10.0)</td>
</tr>
<tr>
<td>Friday</td>
<td>65.9 (11.1)</td>
<td>64.3 (10.4)</td>
<td>64.8 (9.4)</td>
<td>64.6 (9.7)</td>
<td>65.7 (10.9)</td>
<td>68.1 (10.1)</td>
<td>65.2 (10.3)</td>
</tr>
<tr>
<td>Saturday</td>
<td>62.7 (11.5)</td>
<td>58.0* (12.1)</td>
<td>62.3† (10.1)</td>
<td>61.4 (10.6)</td>
<td>64.4 (10.0)</td>
<td>68.4*†(12.2)</td>
<td>62.7 (11.1)</td>
</tr>
<tr>
<td>Sunday</td>
<td>65.5 (11.3)</td>
<td>58.7* (10.5)</td>
<td>62.9† (11.3)</td>
<td>63.5‡ (11.5)</td>
<td>64.9 (9.7)</td>
<td>71.9*‡† (12.4)</td>
<td>64.2 (11.2)</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td>63.2 (10.6)</td>
<td>62.1 (9.7)</td>
<td>63.8 (9.8)</td>
<td>64.3 (10.0)</td>
<td>65.1 (10.8)</td>
<td>68.9 (10.2)</td>
<td>64.5 (10.2)</td>
</tr>
</tbody>
</table>

\(^{3}\)Presented as mean sedentary behavior as percent/day (SD)

**\(\ast\)**\(\ast\)**Denotes significant differences (p<0.05) between age groups for those days
<table>
<thead>
<tr>
<th>Day of week</th>
<th>≥150 minutes/week MVPA</th>
<th>&lt;150 minutes/week MVPA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participants, n</td>
<td>176</td>
<td>117</td>
</tr>
<tr>
<td>Monday</td>
<td>62.8 (9.8)°</td>
<td>65.8 (9.8)</td>
</tr>
<tr>
<td>Tuesday</td>
<td>63.2 (9.2)°</td>
<td>67.9 (10.2)</td>
</tr>
<tr>
<td>Wednesday</td>
<td>63.9 (9.5)°</td>
<td>67.6 (9.5)</td>
</tr>
<tr>
<td>Thursday</td>
<td>63.1 (9.9)°</td>
<td>68.1 (10.1)</td>
</tr>
<tr>
<td>Friday</td>
<td>63.8 (10.0)°</td>
<td>67.4 (9.8)</td>
</tr>
<tr>
<td>Saturday</td>
<td>61.4 (10.6)°</td>
<td>64.6 (11.0)</td>
</tr>
<tr>
<td>Sunday</td>
<td>62.7 (11.3)°</td>
<td>66.4 (11.3)</td>
</tr>
<tr>
<td>Average</td>
<td>63.0 (6.8)°</td>
<td>66.8 (7.8)</td>
</tr>
</tbody>
</table>

*Presented as mean sedentary behavior for percent/day (SD)
†MVPA recommendations from 2008 ACSM/AHA Physical Activity Guidelines
°Denotes significant differences between those adherent to the guidelines and those not adherent
**Figure 4.1.** Sedentary Behavior by Day of the Week in the 7-day cohort
Abbreviations: SB, Sedentary Behavior
**Figure 4.2.** Sedentary behavior by body mass index classification

Abbreviations: SB, Sedentary Behavior

Chapter V

SUMMARY AND CONCLUSIONS

The present study was the largest to examine the variability of sedentary behavior (SB) throughout a typical 7-day measurement period. Previous research has only utilized small cohorts [6, 13, 15] and most used specific cohorts, including older adults [15] or obese individuals [6]. The current study examined male and female adults aged >18 years with various body mass index classifications and physical activity levels. Two cohorts were defined; one requiring 4-days of SB measurement (n=708) and a sub-cohort requiring 7-consecutive days of SB measurement (n=293). Using the 7-day cohort, individual days of the week were compared to each other and no differences in SB were found between days when analyzed separately for males and females and adjusting for age and season of data collection. A larger analysis, including data from 708 adults with at least 4 days of measurement, found no difference in SB between weekdays and weekend days. However, females spent 3% less time in SB on weekend days when compared to weekdays. When determining how many days of measurement were necessary, it was determined that 2 weekdays and 2 weekend days of SB measurement were comparable to 7 days of measurement.

This study provides important information regarding the stability of SB throughout a 7-day measurement period. While no day-to-day variability in SB was found, differences in SB on weekdays and weekend days were noted between males and females. Males were found to be
more sedentary on both weekdays and weekend days than their female counterparts that were more sedentary on weekdays than weekend days. The application of the number of days of measurement is widespread when assessing SB in research. Since 4 days were found to be comparable to 7, the commonly used 7-day period may no longer be necessary. Examining a participant for only 4 days of accelerometry reduces the burden on the participant and the researcher, by limiting wear time and data processing, respectively. Multiple demographic variables were explored in this study and it was determined that gender, age, and season of data collection all play a role in the variability of SB, and therefore should be included when analyzing SB in the future.

**Recommendations for Future Research**

Continued research is needed with nationally representative data sets in order to improve upon the generalizability of the current results. These large-scale, nationally representative data sets examining SB exist and could therefore explore the variability of SB in a sample including proper sampling of all races, ages and gender and BMIs. Similarly, these large data sets could be analyzed to determine nationally representative normative values for SB. If normative values were established, valuable connections between the amount of time spent in SB and unfavorable health outcomes could be clearly established, thus leading to recommendations for limiting time spent in SBs. Furthermore, these normative values would allow for differences in SB to be deemed practically significant. Even though an increased amount of time in SB currently exists, it is not known how much this behavior should be reduced.

As the accuracy of identifying SBs is increasing with advances in technology, examining the variability of SB with monitors that are more precise could provide strong insight into the
stability of SB. While ActiGraph accelerometers are commonly used in SB measurement, some monitors, such as the IDEEA, can accurately identify positions associated with greater than 98% accuracy [29] reducing error that may be associated with less accurate measures. These highly accurate measures of SB should be employed in studies, similar to that of the NHANES, to obtain representative data, as stated previously.
References


