Sedentary lifestyle and obesity in adults

by

Youngwon Kim

A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Kinesiology

Program of Study Committee:
Gregory J. Welk, Major Professor
Frederick O. Lorenz
Duck-Chul Lee
Senlin Chen
Annette M. O’Connor

Iowa State University
Ames, Iowa
2015

Copyright © Youngwon Kim, 2015. All rights reserved.
# TABLE OF CONTENTS

LIST OF FIGURES ........................................................................................................ iv
NOMENCLATURE ......................................................................................................... v
ACKNOWLEDGEMENTS .............................................................................................. vii
ABSTRACT .................................................................................................................. ix

CHAPTER 1. INTRODUCTION .................................................................................... 1
  1.1 References ........................................................................................................... 4

CHAPTER 2. LITERATURE REVIEW .......................................................................... 9
  2.1 Prevalence of Sedentary Behavior ................................................................. 9
  2.2 Definition of Sedentary Behavior ................................................................. 11
  2.3 Detrimental Effects of Sedentary Behavior .................................................. 12
  2.4 Obesity Epidemic ......................................................................................... 14
  2.5 Sedentary Behavior in relation to Obesity ................................................... 17
  2.6 Measurement of Sedentary Behavior ........................................................... 24
    2.6.1 Objective Method ..................................................................................... 24
    2.6.2 Subjective Method ................................................................................... 27
    2.6.3 Objective versus Subjective Methods ..................................................... 30
  2.7 Physical Activity Measurement Survey (PAMS) ........................................... 32
    2.7.1 Background ............................................................................................. 32
    2.7.2 Sampling/Screening ............................................................................... 34
    2.7.3 Data Collection ....................................................................................... 37
    2.7.4 Data Management ................................................................................. 38
  2.8 References ......................................................................................................... 39

CHAPTER 3. THE ACCURACY OF THE 24-HOUR ACTIVITY RECALL METHOD FOR
ASSESSING SEDENTARY BEHAVIOR ........................................................................ 51
  3.1 Abstract ............................................................................................................. 51
  3.2 Introduction ....................................................................................................... 52
  3.3 Method ............................................................................................................. 54
    3.3.1 Sample ................................................................................................... 54
    3.3.2 Instruments ............................................................................................ 55
    3.3.3 Data Collection ....................................................................................... 56
    3.3.4 Data Processing ..................................................................................... 56
    3.3.5 Statistical Analyses ............................................................................... 57
  3.4 Results .............................................................................................................. 58
  3.5 Discussion ......................................................................................................... 60
  3.6 Conclusion ........................................................................................................ 63
  3.7 Acknowledgment ............................................................................................. 63
  3.8 References ........................................................................................................ 63

CHAPTER 4. CHARACTERIZING THE CONTEXT OF SEDENTARY LIFESTYLES IN
A REPRESENTATIVE SAMPLE OF ADULTS: PHYSICAL ACTIVITY
MEASUREMENT SURVEY (PAMS) PROJECT ......................................................... 73
LIST OF FIGURES

Figure 1. Behavioral Epidemiology Framework: Figure from Owen study (33) ......................... 3

Figure 2. A trend of proportions of household with access to computer and Internet use .......... 9

Figure 3. Projected trends of obesity in selected countries: Figure from Wang study (133) ...... 16

Figure 4. A flow diagram of recruitment and enrollment of participants............................... 36
NOMENCLATURE

ATUS; American Time Use Survey

BMI; Body Mass Index

CATI; Computer Assisted Telephone Interviewing

CI; Confidence Interval

CrI; Credible Confidence Interval

CPM; Counts-Per-Minute

CSSM; Center for Survey Statistics and Methodology

DWL; Doubly-Labeled Water

EE: Energy Expenditure

EI: Energy Intake

HR; Hazard Ratio

HOMA\textsubscript{IR}; homeostasis model-estimated insulin resistance

IPAQ; International Physical Activity Questionnaire

MET; Metabolic Equivalents

MetS; Metabolic Syndromes

MVPA; Moderate-to-Vigorous Physical Activity

NHANES; National Health and Nutrition Examination Survey

NSST; Non-Sleep Sedentary Time
NSNLST; Non-Sleep Non-Lying Sedentary Time

OR; Odds Ratio

PA; Physical Activity

PAMS; Physical Activity Measurement Study

PAPQ; Physical Activity Propensity Questionnaire

24PAR; 24-hours Physical Activity Recall

RMR; Resting Metabolic Rate

RR; Relative Risk

SB; Sedentary Behavior

SBRN; Sedentary Behaviour Research Network

SBRS; Survey and Behavioral Research Services

SWA; SenseWear Armband

TST; Total Sedentary Time
ACKNOWLEDGEMENTS

I would like to thank a number of individuals that provided me with considerable help in completing this dissertation work and my doctoral study.

First of all, I thank Dr. Gregory Welk, who is my advisor, for giving me wonderful guidance and support. Indeed, I want to attribute most of my academic achievement to him. He was always willing to share inspirational ideas with me, and offer me many opportunities to work on quality research projects and papers. He knew what my research interests and specialties are, so he helped me maximize my strengths. His feedback was also very thoughtful, thorough and prompt. I strongly believe that without his advice and assistance, I would not have been able to be as successful and productive. Moreover, he was so considerate, patient, friendly and enthusiastic that I really enjoyed working with him. Collectively, I was very fortunate to have him as my mentor and to be able to closely interact with him throughout my doctoral study.

I also would like to thank all our lab members that I have known since I began my Ph.D study. They all work hard all the time and clearly understand what it means to collaborate with one another. Being part of the wonderful lab has enabled me not only to be more academically motivated but also to realize the beauty of feeling connected to each other.

In addition, I thank the dissertation committee for providing valuable insights and constructive comments on the studies performed. I have also received considerable help from all the 5 committee members not only on this particular dissertation work but also on other matters (such as job search, grant proposal, manuscript writing).

I also thank the PAMS project team, which consists of multiple statisticians from the Department of Statistics and staff members from the Survey and Behavioral Research Services
(SBRS), for their contribution to collecting, managing and analyzing the data. I thank the participants as well for their engagement in the PAMS project.

Last but not least, I thank my family members (father, mother and brother) for their unconditional love and support. They are literally living on the opposite side of the globe (South Korea), but they have always cheered me up through regular calls and/or text messages.
ABSTRACT

Excessive time spent on sedentary behavior (SB) can increase the risks of obesity, regardless of engagement in physical activity (PA). Subjective and objective measures are both available to assess SB but little is known about the relative utility of these measures for epidemiological research. The purposes of this dissertation were to 1) evaluate the accuracy of 24-hour Physical Activity Recall (24PAR) relative to SenseWear Armband (SWA) for assessing SB, 2) characterize the context of SB by demographic indicators, and 3) determine the independent/joint associations of SB and PA with obesity by the 24PAR versus SWA.

The first study demonstrated that the 24PAR had small errors for estimating total sedentary time, but larger errors for other definitions of SB (i.e. non-sleep, and non-sleep non-lying sedentary time). Moreover, extremely or minimally sedentary individuals had larger errors than moderately sedentary individuals. Older and/or heavier individuals tended to underestimate sedentary time more than younger and/or lighter individuals. The second study provided unique insights about the context of SB. Individuals with varying levels of socio-demographic variables exhibited differential patterns of ‘where’ and ‘why’ they spent time being sedentary. The third study found detrimental effects of excessive SB and beneficial effects of sufficient PA on obesity based on the objective estimates from the SWA. Analyses based on the subjective estimates from the 24PAR revealed significant associations with the PA outcome but these associations were weaker than the associations with the SWA. These results demonstrate that the objectivity and validity of the measures influences the ability to examine health outcomes.

This dissertation advances understanding about the underlying nature of sedentary lifestyles and its relation to obesity at the population level. The study utilized two promising measurement tools to obtain both objective and subjective measures of SB. The objective tool
served as the criterion and provided strong associations between SB, PA and obesity. The subjective tool was found to have utility for examining the context of SB, but exhibited substantial measurement error, leading to null and/or weak associations with obesity. Future research is required to develop measurement error models to correct for recall biases of the 24PAR.
CHAPTER 1. INTRODUCTION

Excessive time spent on sedentary behavior (SB) is associated with numerous adverse health effects in adults. To be specific, too much time being sedentary has significant relationships with increased rates of (all-cause and/or cause-specific) mortality (5, 8, 24, 26, 29, 44, 47), obesity (4, 6, 11, 17, 37, 41, 45), diabetes (7, 9, 16, 21), cardio vascular diseases (14), and Metabolic Syndrome (MetS) (1, 10, 12, 15, 48). There is strong evidence documenting that the negative effects of SB on health are distinct from effects due to low amounts of moderate-to-vigorous physical activity (MVPA) (1, 17, 20, 21, 25, 29, 39, 40, 48). Therefore, it is clear that SB should not be equated with the lack of physical activity (PA) (i.e. physical inactivity) and/or insufficient amounts of MVPA (35). Unique biological mechanisms specific for SB in relation to health indicators have also now been clearly identified (2, 18, 19).

Historically, MVPA has been the primary outcome measure of interest of PA researchers, but the evidence cited above has led to considerable interest in understanding the impact of SB on health (23). It has been reported that US adults spend over 50% of their waking hours being sedentary (28). The adoption of the contemporary sedentary lifestyle has been directly attributable to the advancement of technology (i.e. Internet, Mobile phones) and the increased use of motor vehicles in our daily lives (36). Reversing these patterns will prove challenging at the societal level but a key step is to better understand the impact of SB on health and the underlying context in which it occurs. Recommendations for designing/conducting/evaluating SB research have been made in an effort to strategically advance research on SB (32-34, 43) but improved measures are needed to better understand and promote SB. Thus, research is needed on
both the cause and consequences of SB and this cannot be accomplished without better measures.

While SB brings upon independent risks to health, it is also widely implicated as a primary contributor to the increasing prevalence of obesity in society (22, 42). In the U.S., nearly 35% of adults are considered obese (13) and studies have documented that obesity is associated with cancers (46), diabetes (30), hypertension (38), sleep apnea (27), coronary heart disease and stroke (3). These types of health outcome research have relied on a wide variety of subjective and objective measurement tools to assess SB. However, the agreement between a subjective and an objective measurement tool for SB assessment has not been studied at the population level, and there is also no clear evidence on the patterns and distributions of measurement errors associated with various types of measurement tools. Given that the choice of measurement tools can potentially modify magnitudes of associations between SB and health outcomes, it is an important public health priority to have a clear understanding of the measurement agreement between different types of assessment tools for SB. Moreover, research is needed to examine the contextual information of SB (i.e. types, purpose, location) at the population level. Research on SB has typically used only “time” spent being sedentary, but little is known about types, purpose and location of SB, in particular from an epidemiological perspective. Furthermore, associations between obesity and SB have not been fully understood thus far. To be specific, there is lack of research to determine whether or not various types of SB (i.e. TV viewing, computer use, sitting time, etc.) have varying levels of associations with obesity. This piece of evidence is important to know since associations of SB with obesity may be moderated by its specific type (i.e. sitting, TV viewing, computer use, etc.). In addition, no study to date has been carried out to investigate both independent and joint associations of SB and MVPA with obesity using both an objective
and a subjective measurement tool in a representative sample of adults. Most previous studies examined independent associations of SB and MVPA with obesity and/or utilized either objective or subjective measurement methods. It is likely that independent and/or joint associations of SB and MVPA vary according to different types of measurement tools used. Addressing these research questions is an important priority for advancing research on SB.

Filling these gaps can be achieved by directly referring to the behavioral epidemiology framework that specifically suggests 6 sequential phases of research to advance science on SB (See Figure 1 below) (33). For example, the first 3 phases of the framework indicate the need for 1) identifying associations between SB and health indicators, 2) using effective measures of SB, and 3) evaluating prevalence rates and specific patterns of SB across various populations, three of which would then inform intervention and/or policies to reduce SB.

Figure 1. Behavioral Epidemiology Framework: Figure from Owen study (33)
The studies utilized data collected as part of the Physical Activity Measurement Survey (PAMS) project to specifically advance research on SB. The overall goal of the PAMS project was to develop a measurement error model to correct for errors inherent in assessing PA with the 24-hours Physical Activity Recall (24PAR; subjective method) in relation to the SenseWear Armband (SWA; objective method) in a representative sample of adults (randomly recruited from Iowa, USA) (31). Each participant’s activity level was assessed with both an objective (i.e. SWA) and a subjective measurement tool (i.e. 24PAR) so the PAMS dataset contains both objective and subjective indicators of SB (and PA) for each individual. The SWA produced accurate estimates of overall SB time, and the 24PAR yielded context information of SB as well as time spent on different types of SB. These features of the PAMS project have made it possible for the above-mentioned research questions to be well-addressed. A comprehensive literature review of key issues will provide background information for the studies conducted.

1.1 References


CHAPTER 2. LITERATURE REVIEW

2.1 Prevalence of Sedentary Behavior

Sedentary lifestyles have become prevalent in contemporary society, primarily due to environmental changes occurring at the societal level, and the drastic evolution of technology. For instance, the proportion of households with access to the Internet and computers has increased by over 500% (from 15% to 79%) over the past 2 decades (i.e. between 1989 and 2012) (1). (See Figure 2) Moreover, there have been dramatic increases in the proportions of Americans working in jobs requiring low levels of energy expenditure (EE) and corresponding decreases in those working in physically challenging jobs (19). In 2010, American adults spent more than 4 hours per day watching TV, and the proportion of American adults with smartphone ownership was nearly 25% (2). Furthermore, over half of U.S. households were found to have high-definition TVs in their homes (2).

![Figure 2. A trend of proportions of household with access to computer and Internet use](image-url)
Prevalence rates of SB at the population level have been reported in previous empirical studies. Matthew et al. (86) estimated the amount of time spent sedentary in the U.S. population. In their study (86), data were obtained from 6,329 participants (i.e. children and adults) that wore an Actigraph accelerometer for at least 10 hours per day as part of the National Health and Nutrition Examination Survey (NHANES). To estimate overall sedentary time from an objective monitoring device (e.g., Actigraph), a cut-point value of 100 counts-per-minute (CPM) (42, 120) was used. The study reported that the overall SB time of the U.S. population was 7.7 hours/day, which is equivalent to approximately 55% of waking hours per day (86). Tudor-Locke et al. (127) also estimated population-level sedentary time from 30,758 working American adults whose SB and PA were assessed with a 24-hours physical activity recall (24PAR) in the American Time Use Survey (ATUS). They (127) documented that on average, working adults in the U.S. spent 4.2 hours being sedentary (outside of sleep/work): 7.8 hours sleeping and 7.5 hours at work. Moreover, they (127) found out that as the intensity category of work increased from ‘sedentary’ to ‘vigorous’, time spent being sedentary outside of sleep/work also increased. Another ATUS study by Tudor-Locke et al. (126) reported and characterized the 10 most frequently reported types of SB in 79,652 U.S. adults as follows (with ‘1’ being the most frequent and ’10’ being the least frequent): 1) “eating and drinking” 2) “TV and movies (not religious)”, 3) “socializing and communicating with others”, 4) “relaxing, thinking”, 5) “Traveling (in a vehicle)”, 6) “telephone calls to/from family members”, 7) “playing games”, 8) “health-related self-care”, 9) attending religious services, and 10) “telephone calls to/from friends, neighbors, or acquaintances”. Contribution of activities to total EE (per day) in the U.S. adults was examined. In a study by Dong et al. (31) using the 24PAR, activity scores (i.e. intensity × duration) were obtained from a total of 7,515 respondents (i.e. males: 3,330)
participating in the National Human Activity Pattern Survey. These were then used to identify the relative contributing roles of different types of activities in accumulating total EE on a given day. It was found out that 10.9%, 9.2% and 8.6% of the total EE were spent on ‘Driving a car’, ‘Job: office work, typing’ and ‘Watching TV/movie, home or theater’, respectively (31), all of which are considered typical sedentary activities for adults. A study by Evenson et al. (41) found that objectively estimated SB time (i.e. with the Actigraph monitor) for 2,630 older adults (aged >60yrs) in the NHANES study was 8.5 hours per day. The reports above are primarily from the U.S. but Bauman et al. (11) conducted a review study to provide worldwide estimates of sitting time in 49,493 adults from 20 countries using data from the International Physical Activity Questionnaire. The median sitting time was 5 hours per day.

2.2 Definition of Sedentary Behavior

There is currently no universally agreed-upon consensus on the definition of SB, even though a great deal of attention has been paid to research on SB. This has made it challenging to make direct comparisons between studies on SB (95, 96). SB is often operationally defined as any activity yielding EE values ≤1.5MET (97). A MET value of 1 is used to define the EE level of an individual at rest, so 1.5MET indicates one’s EE level that is 1.5times greater than his/her resting metabolic rate (RMR) (5). However, the methodology to define SB with the 1.5MET cut-point may be potentially problematic since it cannot differentiate sleeping from waking activities, and sitting from standing, thereby leading to overestimation of overall time spent sedentary. Another way to operationally define SB is equating sitting with SB (98). Even though most sedentary activities (e.g. computer use, watching TV, driving a car) are performed while seated, sitting per se may not be fully representative of SB. Moreover, one can burn large amounts of Calories (over 1.5METs) in a sitting posture when weight-lifting and/or riding a
bicycle. Recently, the Sedentary Behaviour Research Network (SBRN) group (9) proposed a way of defining SB in an effort to create agreement among researchers about how SB should be defined. In their report, SB was defined ‘as any waking behavior characterized by an EE ≤1.5 METs while in a sitting or reclining posture’. It is important to note that this definition takes into account non-sleep time (i.e. waking), EE (i.e. ≤1.5MET) and posture (i.e. sitting/reclining). This has gained attraction for use with adults but the cut-point of 1.5MET for youth may cause EE to be underestimated in youth. Since children’s RMR is known to be higher than adults’ RMR, it makes sense that the corresponding MET cut-point for estimating SB time for youth should be also higher than that for adults. In our unpublished research (by Saint-Maurice et al.), we identified that 2.0MET showed higher classification accuracy than the traditional 1.5MET cut-point in identifying sedentary activities in youth.

2.3 Detrimental Effects of Sedentary Behavior

Numerous independent health outcome studies have identified detrimental effects of excessive time spent sedentary with mortality rates (23, 32, 74, 77, 88, 129, 135), diabetes (30, 33, 49, 67), MetS (8, 34, 48, 141), and individual metabolic risk factors (7, 8, 33, 49, 59, 62-64, 67, 117, 142). Unique biological mechanisms through which SB is associated with health have been also identified (13, 57, 58).

Differences in designs and methods make it difficult to draw definitive conclusions from individual studies but several systematic review and meta-analysis studies (39, 47, 73, 75, 118, 143) have clarified and quantified the impact of excessive amounts of time spent sedentary and deleterious health outcomes for adults. To be specific, a study by Wilmot et al. (143) performed a systematic review and meta-analysis on 18 studies (i.e. 16 prospective and 2 cross-sectional
studies; a total of 794,577 participants) that investigated relationships of SB with diabetes, CVD and mortality rates. They (143) reported that larger amounts of time spent sedentary were significantly associated with increases in the relative risk (RR) of having diabetes (RR: 2.12 with 95% credible interval (CrI) from 1.61 to 2.78), increases in the RR of having cardiovascular events (RR: 2.47 with 95% CI from 1.44 to 4.24), increases in hazard ratio (HR) of cardiovascular mortality (HR: 1.90 with 95% CrI from 1.36 to 2.66), and increases in HR of all-cause mortality (HR: 1.49 with 95% CrI from 1.14 to 2.03). A report by Ford et al. (47) reviewed 37 prospective studies that examined the relationships between SB (i.e. screen time and sitting) and fatal/non-fatal CVD. A systematic review of these studies revealed that the highest levels of screen time and sitting time were associated with 125% and 68% increases, respectively, in the risk of CVD, compared with the lowest levels of sedentary time. A subsequent meta-analysis (i.e. six studies on screen time and two studies on sitting) from the same set of studies demonstrated that every 2-hour increases in daily screen time and sitting time were associated with 17% greater risk for CVD (HR: 1.17 with 95%CI: 1.13–1.20) and 5% greater risk for CVD (HR: 1.05 with 95% CI: 1.01–1.09), respectively (47). Katzmarzyk et al. (73) systematically reviewed 5 large-scale cohort studies that examined associations of SB (i.e. daily sitting time, TV viewing, riding in a car) with mortality rates (i.e. all-cause, CVD, and cancer). Some of the 5 studies reviewed identified significant associations of SB with all-cause and CVD mortality; however, none of them found a significant association with cancer mortality. Another review study conducted by Katzmarzyk et al. (75) revealed that reducing daily sitting time to less than 3 hours would allow U.S. adults (i.e. NHANES data) to gain an average of 2 additional years of life: 1.38 years gain from reducing daily TV viewing time to less than 2 hours. Edwardson et al. (39) conducted a meta-analysis on 10 cross-sectional studies (a total of 21,393 adults) that examined
the associations of SB with MetS. They (39) obtained a pooled odds ratio (OR) value of 1.73 (i.e. 95% CI: 1.55 - 1.94), indicating that adults with greater sedentary time would have 73% increased odds of having MetS. Collectively, these studies show negative effects of too much time spent being sedentary on varying types of health outcomes.

It is important to emphasize that studies have consistently identified deleterious effects of excessive SB with various health outcomes, independent of PA (8, 22, 54, 62, 63, 65, 67, 76, 88, 112, 113, 141, 142). In determining this type of independent associations of SB with health, two ways of regression model methods have been used (73). For instance, in performing sequences of multiple multivariate regression models to regress sedentary time (and a series of covariates) against a health indicator, a PA variable is added in the final multivariate model. If the PA variable is not a statistically significant covariate and/or the coefficient value of sedentary time does not considerably change in the final multivariate regression model compared with the prior model (with no PA variable included), one would conclude that SB is significantly associated with the health indicator, independent of PA. Another way to identify independent association of SB is stratifying participants’ sedentary time according to the levels of PA. If significant associations between sedentary time and a health indicator are consistently observed across all stratified PA levels/groups, it would be concluded that SB has a significant relationship with the health indicator, irrespective of PA.

2.4 Obesity Epidemic

Obesity is a major public health concern in countries across the world. The current obesity prevalence of American adults is nearly 35% (44). Evidence indicates that, in general, the 1980s are the beginning of the obesity pandemic globally (43) as well as in the U.S. (45).
This global obesity pandemic has been primarily attributable to societal/environmental changes (rather than biology) (68, 116). Another reason may be substantial declines in time spent being physically active and increases in time spent sedentary, mainly due to the advancement of multimedia (i.e. Internet, Mobile Phones) and the increased use of motor vehicles over the past 3 decades (99). Globally, remarkable annual increases in BMI (i.e. 0.4 kg/m² for each year) have been identified since 1980. However, in the U.S., obesity prevalence has been static for the past decade (i.e. between 2000 and 2010) (44, 46, 105), while it dramatically increased by nearly 55% over the two prior decades: between 1976 (i.e. 14.5%) and 1994 (i.e. 22.5%). While these trends suggest a plateau in prevalence, it may be too early to confirm this pattern. A recent study indicates that “record-high” obesity prevalence rates may be observed as cohorts of young adults born in the 1980s (i.e. particularly exposed to the drastic obesogenic societal changes) reach their peak obesity prevalence (104). This was well-illustrated in a previous OECD report (108). As seen in Figure 2 (copied from Wang et al. study (133)), an estimated prevalence rate of overweight will continue to increase from 2010 onwards until 2020 (after the plateau between 2000 and 2010) in the U.S. as well as in other countries. According to the projections, by 2020, nearly 75% of American adults will likely be considered overweight. It is also noteworthy that the accelerating rate of the overweight prevalence for the next decade is almost identical to that between 1980 and 2000.
Figure 3. Projected trends of obesity in selected countries: Figure from Wang study (133).

There are tremendous health and economic burdens on society imposed by the obesity epidemic. A large number of studies identified harmful effects of obesity with various types of chronic diseases, such as cancers (132), diabetes (93), hypertension (109), hyperlipidemia (102), sleep apnea (79), coronary heart disease and stroke (15). Wang et al. (133) systematically examined potential health and financial burdens associated with the obesity epidemic for which the U.S. and the U.K. are responsible for the next two decades, using a simulation approach. They (133) estimated that by 2030, the number of obese adults would increase by 65 million in the U.S., and 11 million in the U.K.: 6 – 8.5 million for diabetes, 5.7 - 7.3 million for heart disease and stroke, 492,000 – 669,000 for cancer, and 26 - 55 million for quality-adjusted life years (i.e. U.S. and U.K. combined). Annual increases by 2030 in health cost to treat these
diseases (including obesity) are $48 - 66 billion for the U.S. and £1.9 - 2 billion for the U.K. In another study by Wang et al. (134), prevalence rates of overweight and obesity were expected to increase up to 86.3% and 51.1%, respectively, by 2030. As a result of this continuing, dramatic increase in obesity prevalence, obesity-attributable medical costs will account for between 16 and 18% of the total U.S. health care expenditure by 2030. Withrow et al. (144) demonstrated that between 0.7% and 2.8% of total expenditure on health care systems in a nation were attributable to obesity. In addition, total health costs were about 40% larger for obese adults than for normal adults. Thorpe et al. (119) reported that approximately 12% increases in medical costs between 1987 and 2001 were associated with the drastic increases in prevalence rates of obesity that occurred during the same time period.

2.5 Sedentary Behavior in relation to Obesity

Multiple factors have played roles in creating the contemporary obesity epidemic, but a lifestyle change (from physically active to sedentary) is one of the key factors. There have been dramatic increases in multimedia use (i.e. computer, TV, Internet), motor vehicle use for transportation, and substantial decreases in the number of physically intense professions (68, 99). These types of sedentary lifestyles have led to reductions in EE, while excessive consumption of unhealthy foods have led to increases in energy intake (EI). Even small individual changes in EE and EI can lead to systematic energy imbalance (i.e. EI exceeds EE) and population changes in obesity. The contemporary obesogenic society is likely attributable to this energy imbalance from changing from physically active lifestyles to sedentary lifestyles (in conjunction with increases in intake of unhealthy foods).
Much research has been conducted to investigate the deleterious effects (and specific patterns) of sedentary behavior in relation to obesity. Matthew et al. (88) indicated that for obese adults, ≥5 hours/day of TV viewing were significantly associated with all-cause mortality, whereas significant associations were observed with ≥3 hours/day of TV viewing for normal weight or overweight adults. Proper et al. (100) found out that adults with 1170–1859 min/week and ≥1860 min/week of leisure-time sitting were 52% and 105% greater odds of being overweight or obese, respectively, compared with those with <1170 min/week, after adjustment of all covariates included. They (100) also indicated that males, older individuals (i.e. 34-49 yrs, 50-65 yrs), and adults with lower neighborhood socio-economic status were more likely to be overweight or obese. In a study by Tudor-Locke et al. (125) using NHANES data, overweight or obese individuals were found out to show more time spent sedentary, to have a smaller number of breaks in sedentary time, and to be less likely to adhere to the PA guidelines (128), compared with normal weight individuals. In a prospective cohort study by Meyer et al. (92), greater TV viewing time was significantly associated with 43% greater odds (1.43, 95% CI 1.29, 1.58) of being overweight or obese at baseline in a sample of 12,678 adults, but no significant association at the 6-years follow-up. Bowman et al. (17) demonstrated that obese people spent 3 hours/day, which was greater than time spent watching TV for normal weight (2.3 hours/day) and overweight (2.6 hours/day) individuals: data from the U.S. Department of Agriculture survey with 9,157 adults. Another finding was that >2 hours/day of TV viewing were associated with greater levels of BMI, and greater proportions of being overweight or obese in comparison with <1 hour/day of TV viewing (17). McDowell et al. (91) reported that overweight or obese individuals had worse indicators of self-reported health, health care civilization, limitation in daily activities, joint pain, shortness of breath, and low back pain, compared with normal weight
individuals. Another relevant study by De Cocker et al. (29) demonstrated that women who gained weight over time showed higher increases in sitting time (>5%) compared with those who lost weight during the same time period, and women whose sitting time increased had higher increases in BMI values (>20%) than those whose sitting time decreased.

A prospective cohort study by Ekelund et al. (40) provided a unique piece of evidence by demonstrating that obesity indicators (i.e. BMI, fat mass, WC) predicted future sedentary time. Even more surprising was the fact that time spent being sedentary did not predict future obesity. To my knowledge, this is the only study that argues a reverse direction of causality of SB in relation to obesity. More studies (preferably, cohort and/or randomized controlled studies) are clearly needed to identify the true direction of causality between SB and obesity in adults.

Evidence indicates that the most commonly used type of SB in research is TV viewing, followed by computer use and overall sitting time (103). While each of these types represents its own unique relationships with health, they are closely related to each other. For example, one can watch a movie sitting in a chair, or on a computer screen. Hence, it is essential to untangle the complexities and inter-relations of different types of SB. Previous studies have provided some insights about how associations of SB with obesity indicators and health outcomes vary by specific types of SB. Rhodes et al. (103) conducted a systemic review study to provide an overview of correlates of SB. From 109 papers reviewed, they (103) found out that levels of evidence (i.e. positive, negative, indecisive, none) for correlates of SB differed depending upon types of SB. For instance, in studies using TV viewing (n=29) BMI was positively correlated with TV viewing. However, indecisive evidence was obtained with computer use. Similar patterns of findings were identified for other health indices and/or socio-economic variables. Hu et al. (69) conducted a prospective cohort study where 50,277 women were followed up for 6
years from 1992 to 1998 in the Nurses’ Health Study. They (69) found out that every 2-hour increment in ‘TV viewing’ was associated with a 25% (95% CI: 17% - 30%) and 14% (95% CI: 5% - 23%) increase in the risk of being obese and diabetic, respectively. Substantially lower risks of obesity (RR of 5%; 95% CI: 0-10%) and diabetes (RR of 7%; 95% CI: 0-16%) were observed with every 2-hour increment in ‘sitting at work’. Dunton et al. (35) carried out a study to determine the degree to which types of SB affect associations with BMI, and to examine interaction effects of MVPA and SB on BMI, using cross-sectional data from the 2006 ATUS study (i.e. 10,984 non-underweight adults). They (35) employed a self-report method (i.e. 24PAR) and estimated time spent in different types of SB: ‘Watching TV/ Movies’, ‘Computer use’, ‘Playing games’, ‘Reading’, ‘Sedentary transportation’, and ‘Total sedentary time’. Multiple multivariate linear regression analyses (examining relationships between different types of SB and BMI) revealed that the regression coefficients (i.e. beta) substantially varied by type of SB, ranging from -0.22 (i.e. ‘Reading’) to 0.747 (i.e. >320min/day of ‘Total sedentary time’). Moreover, the magnitude of interaction effects of MVPA and SB also differed depending on different combinations of MVPA and SB: significant interactions for leisure MVPA × Watching TV/Movies, Leisure MVPA × Playing games, Active transportation × Sedentary transportation, and Active transportation × Reading (35). A similar pattern of findings was observed from the Heinonen et al. study (66) where associations of multiple types of SB (i.e. TV viewing, computer use, reading, music/radio listening and other relaxation) with BMI and WC were examined in 1993 Finnish adults. It was found that correlation coefficients for both BMI and WC considerably varied by SB types (66). In addition, different types of SB had varying levels of regression coefficients (i.e. beta; from multi-variate regression analyses) with WC (66). Other studies found that effect sizes of associations with other health outcomes (i.e. all-cause mortality,
cardiometabolic diseases (23), and metabolic risk factors(117)) considerably vary in accordance with specific types of SB.

Combined effects of SB and PA on obesity have also been investigated, using either the multi-variable regression analyses (i.e. adding PA in the final model) or the stratification method (73). To be specific, Qi et al. (101) found significant interaction effects of excessive sedentary time (i.e. TV viewing) and leisure-time PA with calculated genetic risk scores, each independently related to BMI in 7740 women and 4564 men in the Nurses’ Health Study and the Health Professionals Follow-up Study. Another prospective cohort study (i.e. Nurses' Health Study) by Hu et al. (69) demonstrated that using multi-variable regression analyses (adjusting for all included covariates plus exercise levels), every 2hour increment in TV viewing and sitting at work was significantly associated with 23% and 5% greater risk of being obese, respectively, independent of PA. Sugiyama et al. (115) also identified significant associations of SB with overweight or obesity, regardless of MVPA, employing the stratification method. For instance, 2210 adults were stratified into one of the following four combinations of SB and MVPA: 1) low sedentary time (i.e. below median) and high MVPA time (i.e. greater than 2hours per week), 2) low sedentary time and low MVPA time (i.e. less than 2hours per week), 3) high sedentary time (i.e. above median) and high MVPA time, and 4) high sedentary time and low MVPA time. In comparison to the reference group (i.e. Group 1; low sedentary and high MVPA), logistic regression analyses revealed that Group 2, 3, and 4 had 54% (i.e. 95%CI: 1.20-1.98), 55% (i.e. 95%CI: 1.20-2.02) and 126% (i.e. 95%CI: 1.75-2.92) greater odds of being overweight or obese, respectively. When it comes to comparing between Group 1 and 3, and between Group 2 and 4, the OR values increased as sedentary time increased, irrespective of levels of MVPA. Salmon et al. (107) found out that more than 1 hour per day of TV viewing was associated with greater
odds (OR ranges from 1.93 to 4.14) of being overweight in 3,392 Australian adults. Another important finding was that across 3 of the 4 PA levels (i.e. inactive, low, moderate, high), the odds of being overweight or obese for adults that viewed TV for more than 4 hours per day were more than twice larger than those for adults that viewed TV for less than 1 hour per day (OR ranges from 2.0 to 2.2) (107), which indicates associations of TV viewing, distinct from PA. Chau et al. (24) identified significant associations between SB and overweight and obesity, distinct from PA levels, in 10,785 Australian adults. To be specific, observed RR values of being obese were larger for adults with mostly sitting (compared with mostly standing) and smaller for adults with less than 4 hours per day of leisure-time sitting (compared with 4 or more hours of daily sitting), controlling for all other covariates (including PA and occupational PA) in the Cox proportional hazard regression model. Vandelanotte et al. (131) found out that adults with high Internet and computer use had 46% and 152% greater odds of being overweight and obese, respectively, after adjustment for gender, age, employment, educational background, other sedentary behaviors, and leisure time PA. Another finding was found from a joint association analysis that greater time spent on the Internet and computer use was associated with greater odds of being overweight or obese. For instance, the high Internet and low leisure-time PA group had 277% greater odds of being overweight or obese compared with the no Internet and computer use and high leisure-time PA group (131). Maher et al. (82) (i.e. employing a stratification method) identified joint associations of SB and MVPA with obesity in 5,083 NHANES adults. A unique feature of that study (82) was that an objective method (i.e. Actigraph accelerometer) was used to estimate MVPA, and a subjective method was used to estimate TV viewing time and total sedentary time. The resulting findings were that inconsistent positive associations with obesity were identified for TV viewing across three categories (i.e.
low, moderate, high) of MVPA; however, no significant associations were detected from parallel analyses with total sedentary time. Interestingly, MVPA had consistent significant associations with obesity, irrespective of types (i.e. TV viewing and total sedentary time) and categories (i.e. low, moderate, high) of SB. These findings indicate that adulthood obesity is more strongly associated with MVPA in comparison with TV viewing or overall sedentary time (82). Cleland (27) found out that the odds of being obese was greater for both men (OR: 2.68, 95%CI: 1.36 – 5.32) and women (OR: 2.66, 95%CI: 1.58 – 4.99) with high sitting and low steps compared with those with low sitting and high steps; greater ORs for both men (OR: 1.95 95%CI: 1.01 – 3.79) and women (OR: 2.00, 95%CI: 1.21 – 3.31) with high sitting and low PA compared with those with low sitting and low PA. The stratification analyses by Dunton et al. (35) revealed that there were significant interaction effects between SB and PA for the following combinations: “leisure MVPA × TV/movies”, “leisure MVPA × playing games”, “active transportation × sedentary transportation”, and “active transportation × reading” (all P-values less than 0.0001). To be specific, smaller BMI values were observed for adults with less than 60 minutes of daily TV viewing and greater than 60 minutes of daily leisure-time MVPA than for those with less than 60 minutes of daily TV viewing and less than 60 minutes of daily leisure-time MVPA (35). Stamatakis et al. (114) also identified significant associations of sedentary time (i.e. TV viewing and other screen-based activities) with both BMI-defined and WC-defined obesity, independent of time spent in MVPA. Gennuso et al. (54) found significant positive associations between accelerometer-derived sedentary time and BMI (and other biomarkers as well), adjusting for demographic variables plus MVPA, in 1,914 older adults in the NHANES study.
2.6 Measurement of Sedentary Behavior

Selecting a measurement tool is a particularly important consideration in designing, implementing and evaluating epidemiological studies. Depending upon different types of measurement tools, estimates of time spent being sedentary (and physically active) would vary, and different aspects would be considered in planning a study. Subjective methods have been widely used for large-scale epidemiological surveillance and/or intervention studies because they are relatively inexpensive and less burdensome on participants compared with objective methods, but objective methods have the advantage of greater accuracy. In general, measurement tools are used interchangeably between studies focused on SB and PA. However, there are certain characteristics that need to be considered for selecting a measurement tool specific for research on SB. To address this, specific characteristics of both objective and subjective methods and inter-relations between them with respect to SB research for adults are described in the following sections.

2.6.1 Objective Method

Objective measurement has come into widespread use in contemporary research of SB (and PA). There are various types of objective measurement tools such as pedometers, heart rate monitors, accelerometers, multi-sensor monitors, inclinometers, indirect calorimetry, doubly-labelled water (DLW), etc. Substantial efforts (10, 50, 136, 138) have been made in order to improve the utility/efficacy/accuracy of these objective monitoring tools. The most appealing aspect of objective measurement is that it provides relatively accurate estimates of SB and PA since it does not take into account the subjectivity of participants and/or researchers. For example, an accelerometer worn on a participant would constantly record his/her body movements and yield corresponding estimates of SB and PA levels, thereby limiting the
likelihood for him/her to manipulate the raw values obtained from the accelerometer. Some disadvantages of using objective measurement tools are high cost, relatively high burden on participants, and the necessity of advanced data processing techniques to reduce the data and to screen for reactivity and compliance (123).

Various types of accelerometry-based activity monitors have been used in research to estimate SB (and PA) time for adults. The Actigraph (Actigraph LLC, Pensacola, FL, USA) is a small (4.6 cm × 3.3 cm × 1.5 cm) and light (19g) tri-axial accelerometer that is commonly worn on the right hip of a person and detects any bodily movements that occur at three axes (i.e. vertical, anterior-posterior and medial-lateral). While the Actigraph is one of the most widely adopted accelerometers, there exists a debate about the best method for processing raw data to estimate time spent being sedentary. Raw data collected from the Actigraph are expressed in CPM. However, this CPM does not have a specific measurement unit associated with it, even though larger CPM values indicate more body movements. Thus, researchers invented a cut-point method where different intensities of physical activity are differentiated at a certain value of CPM. For identifying SB time, a 100CPM value has been widely used in research, but previous validation studies demonstrated that the 100CPM cut-point has low accuracy for adults (78), but high accuracy for children (137), in estimating SB time. Freedson et al. (51) has advocated for the use of machine-learning techniques for processing data obtained from the Actigraph, but the accuracy of the technique in classifying sedentary activities for adults has not been fully confirmed yet.

Another commonly used accelerometry-based activity monitor is the SenseWear Armband (SWA) (BodyMedia®, Pittsburg, PA). In contrast to other types of accelerometer-based objective monitoring devices, the SWA is equipped with multiple sensors (heat flux, galvanic
skin response, skin temperature, near body temperature) as well as a tri-axial accelerometer. The SWA is instructed to be worn on the middle of triceps of the non-dominant arm. A unique characteristic of the SWA is that the proprietary algorithms used to process data are periodically updated by the manufacturer (i.e. Bodymedia, now acquired by Jawbone) over time, which makes it possible to provide more accurate estimates of SB and PA. The SWA has proven to be valid in estimating EE and time spent in different intensities of PA for adults in relation to various types of reference methods such as DLW (72), indirect calorimetry (52, 81), and a pattern-recognition technology (i.e. IDEEA) (139). In regards to the utility of the SWA in assessing SB for adults, previous studies demonstrated significant test-retest reliability between two different testing days (i.e. r=0.62 with p<0.05) (18) and minimal mean differences (i.e. non-significant) when compared with the criterion measures (139, 140).

While accelerometry-based activity monitors are still frequently used in research on SB, another type of objective monitoring devices using “inclinometers” has received particularly high attention for its ability to distinguish different types of posture: lying down, sitting, standing, and stepping. The activPAL (PAL Technologies Ltd, Glasgow, Scotland) is one of the most broadly used inclinometers to assess SB and PA, and it has capacity to estimate time spent in different types of posture and EE values. Numerous validation studies have now supported its validity and reliability in assessing time spent sedentary for children (6, 28, 70) and adults (56, 78, 80). With respect to the accuracy for assessing adults’ SB, the activPAL has been shown to be more accurate in comparison with the traditionally used cut-point method (i.e. 100CPM) with the Actigraph (78, 80). Even though the activPAL shows high classification accuracy in identifying sedentary activities, whether it would provide accurate estimates of EE remains
questionable (71). However, it is clear that the activPAL has great potential to accurately assess SB among adults.

2.6.2 Subjective Method

A wide variety of subjective methods have been adopted in studies to assess SB and PA: questionnaires, recall surveys, diaries, activity log, etc. Subjective measurement tools provide not only estimates of time and EE, but also detailed characteristics of SB and PA. In addition to obtaining the context information, subjective methods have other advantages over objective methods, such as low cost, ease of use, relatively low burden on participants, ease of data processing, etc. However, subjective measures are also more prone to measurement errors (i.e. recall bias (38), social desirability and social approval bias (3)), which can presumably result in less accurate estimates in comparison with objective methods. Self-report measures are considered useful particularly for epidemiological, intervention and surveillance studies (60), but in order to further improve the utility and minimize errors of subjective methods, a comprehensive series of studies (i.e. all of which published in *Journal of Physical Activity and Health* as supplements) have proposed best practices of utilizing self-report measurement tools (4, 16, 84, 122).

Traditional questionnaires are composed of only a single-item question (i.e. domain specific or overall time) and/or multiple question items asking about general activity patterns requiring relatively longer periods of recall (i.e. 7days, 14days, 30days, past month or past year). Reliability and validity of this type of traditional self-report measures to assess SB have been summarized in a previous review study by Healy et al.(61). They (61) provided general characteristics and indicators of reliability and validity for different types of questionnaires designed to assess overall (i.e. total SB time) and domain-specific (i.e. TV viewing, computer
use, sitting, worksite, transportation) time spent sedentary. In regard with reliability, moderate-to-high correlations were observed for most of the self-report methods reviewed, and relatively larger correlation values were identified for regularly performed and/or prolonged sedentary activities (i.e. sitting at work and TV viewing) than for irregularly occurring sedentary activities (i.e. travel). When it comes to validity, low-to-moderate correlations were detected for the majority of studies reviewed. Moreover, both underestimation and overestimation of sitting time were identified for the self-report methods in relation to reference methods. However, it is important to note that nearly all the original validation studies reviewed above used accelerometer-based activity monitors as the reference methods. While this is defensible, it is important to note that accelerometers are not considered a “gold standard” method (61), especially for assessing SB. The lack of a true criterion makes it challenging to have a true understanding of validity of self-report methods about assessing SB. This conclusion was also reached in another systematic review study by Clark et al. (25). They demonstrated moderate-to-high levels of reliability, but varying levels of validity depending on different types of reference methods used and the different self-report methods to assess TV viewing and non-occupational indicators of SB. That study (25) also pointed out the lack of true gold standard references against which self-report are validated. A recent independent validation study by Besson et al. (12) reported that a self-report method (i.e. Recent Physical Activity Questionnaire) relative to the DLW method (i.e. gold standard method) showed a small insignificant correlation ($r=0.27$ with p-value of 0.06) and minimal mean difference (0.7 hours per day). Overall, traditional self-report methods are reliable, but whether or not they are valid is indecisive.

Previous studies by Sallis et al. (106) and Matthews et al. (90) documented that short-term recall methods can reduce measurement errors of (traditional) self-report methods that
occur mainly due to long recall periods. Another study demonstrated how cognitively challenging it is to recall one’s activity patterns for the past month in a very systematic way. Moreover, traditional self-report measures do not usually provide specific details of contextual information on SB and PA even though corresponding types are reported. Thus, the 24PAR method has received particularly high interest (over recent years) since it requires only a recall of the previous day, and provides highly detailed understandings of where, for what purpose, and with whom a respondent performed a certain type of activity.

The 24PAR method that investigates patterning of one’s time use (i.e. commonly referred to as a time-use survey) on the previous day has been utilized in numerous epidemiological surveillance and health outcome studies on SB and PA (35-37, 126, 127). Moreover, a number of previous studies have empirically investigated and confirmed its utility in assessing SB for adults. To be specific, a previous study by Matthews et al. (89) examined the validity of the 24PAR in assessing time spent sedentary and physically active in a large sample (i.e. 88 adults and 81 adolescents). The 24PAR was found out to be valid in relation to the activPAL for assessment of sedentary time, with correlation coefficients ranging from 0.52 to 0.80. (89). Another study by Clark et al. (26) identified moderate test-retest reliability (i.e. intra-correlation coefficient of 0.5) and small (significant) responsiveness (-0.44) as well as high validity (mean difference of -9min equivalent of 1.8% with p-value of 0.61) in relation to the activPAL (i.e. reference method) on breast cancer survivors. Test-rest reliability of the 24PAR was also demonstrated in a study by Van der Ploeg et al. (130) that observed an intra-class correlation coefficient of 0.74 for non-occupational SB in a sample of 134 adults; however, relatively low validity (relative to the Actigraph) was indicated by small Spearman correlations ranging from 0.39 to 0.59 and large mean differences ranging from -74min/day to 49min/day (i.e. proportions
ranging from -37% to 40%). When it comes the use of the 24PAR for assessment of “PA” in adults, relatively high validity was identified in previous validation studies (20, 55, 85, 110, 137). Overall, the 24PAR method has proven promising to serve as a measurement tool to assess SB (and PA) for surveillance/health outcome/intervention studies. However, further research is clearly needed to validate it against stronger reference methods (such as DLW and/or indirect calorimetry).

2.6.3 Objective versus Subjective Methods

Objective and subjective measurement tools each have advantages and disadvantages, so it is challenging to favor one method over the other. Recommendations by Troiano et al. (122) and Healy et al. (61) indicated that one of the recommended research practices on SB is incorporating both objective and subjective methods, which would then enable researchers to gain more accurate estimates and more fruitful contextual information of SB.

The influence of selecting a method type – either objective or subjective – on surveillance of SB (and PA) has been well documented. For instance, Tucker et al. (124) demonstrated using NHANES data that by self-report measure, nearly 62% of US adults adhered to the 2008 US Physical Activity Guidelines (128) (i.e. 150minutes of MVPA per week), whereas less than 10% of them met the guidelines by Accelerometry (i.e. Actigraph). A very similar pattern of findings was observed from another surveillance study by Troiano et al. (121); the prevalence rate of compliance with the PA guidelines (128) was over 50% by self-report, but it was only 5% by accelerometer. Healy et al. (61) demonstrated the differences in population estimates of SB time between using objective and subjective measures using NHANES data. For men, significant differences in overall sedentary time were observed for age trends by ethnicity group when SB was assessed with an objective method (i.e. Actigraph accelerometer), but no significant
differences with a self-report method. For women, in contrast, the self-report measures (i.e. sitting time, screen-based time, TV viewing time, and computer use) identified significantly different age trends across different ethnicity groups; however, no difference was detected with the Actigraph accelerometer. The three above-mentioned studies (61, 121, 124) illustrate the importance of selecting measurement types in carrying out surveillance studies on SB and PA.

Matthews et al. (90) indicated that measurement errors associated with self-report methods are likely to lessen true associations of SB (and PA) with health outcomes. Stronger associations between PA and health indices when using self-report methods (vs. objective methods) have been identified in previous studies (7, 14, 83). However, to date, only two studies (22, 111) have examined the impact of choice of a method type on associations of SB with health outcomes in adults. For example, Celis-Morales et al. (22) used Actigraph accelerometers (i.e. objective) and International Physical Activity Questionnaire (IPAQ) (i.e. subjective) to estimate sedentary time, and determined if there are differences in magnitudes of associations with cardio-metabolic risk factors in a sample of 317 Chilean adults. The risk biomarkers included were insulin, glucose, triglyceride, cholesterol concentrations (i.e. total, LDL and HDL), homeostasis model-estimated insulin resistance (HOMA_{IR}), waist circumference, BMI, body fat percentage and blood pressure. Accelerometer-derived sedentary time (objective) was significantly associated with all the risk factors (p-values smaller than 0.05) whereas sedentary time from the IPAQ (subjective) had significant associations only with insulin and HOMA_{IR}. Moreover, the size of associations (i.e. beta coefficients) was much larger with accelerometer data. Similar patterns of findings were observed for MVPA. Stamatakis et al. (111) conducted a very similar study to investigate associations of SB with cardio-metabolic risk factors using the Actigraph accelerometer versus a self-report method in 2,765 British older adults (age ≥ 60yrs). Multiple
indicators of SB (total SB time, TV viewing time, non-TV viewing sitting time) were obtained from the self-report, and 4 main risk factors of interest were BMI, waist circumference, cholesterol ratio (total/HDL), and Hb1Ac. With respect to associations using the self-report, 3 of the 4 cardio-metabolic risk factors (BMI, waist circumference, cholesterol ratio) were significantly associated with total SB time and TV viewing time, but no significant association with non-TV viewing sitting time. Accelerometer-derived total SB time showed significant associations with 2 of the 4 risk factors (waist circumference, cholesterol ratio). However, it is insightful to compare the magnitude of associations for the 2 risk factors that were found out to be significant both by the self-report and accelerometer. Associations (i.e. beta coefficients) with accelerometer data were considerably larger for total SB time (waist circumference: 0.633, cholesterol ratio: 0.060) than similar relationships with self-reported total SB time (waist circumference: 0.234, cholesterol ratio: 0.018), and TV viewing time (waist circumference: 0.413, cholesterol ratio: 0.021). Both of the studies (22, 111) confirmed the commonly accepted notion that stronger associations with health are observed with objective methods than with subjective methods.

2.7 Physical Activity Measurement Survey (PAMS)

2.7.1 Background

The Physical Activity Measurement Survey (PAMS) is a 5-year NIH-funded project. The primary goal of the project was to develop a measurement error model to correct for errors inherent in the self-report method (i.e. 24PAR) in relation to the objective monitoring tool (i.e. SenseWear Armband Pro III; SWA). A 24-hour recall method has been widely used to estimate
dietary intake in national surveillance studies. Moreover, measurement error models to adjust for
errors associated with the 24-hour dietary recall have been developed by Nusser et al. (94) and
Carriquiry et al. (21), and have been incorporated into large-scale studies to estimate EI.
However, no such effort has been made for the 24PAR in estimating EE and PA. Hence,
developing a measurement model for the 24PAR was necessary, and this would potentially allow
for direct comparisons between error-adjusted EI and EE as well as joint modeling of EB.

As previously mentioned above, the SWA is a powerful, multi-sensor monitor that has
been previously shown to provide valid estimates of EE and PA. Therefore, in this study, the
SWA served as the criterion reference method in developing measurement error models for the
24PAR. The PAMS project was planned and carried out through multi-disciplinary collaborative
work among three major parties at Iowa State University: Department of Kinesiology,
Department of Statistics, and the Center for Survey Statistics and Methodology (CSSM). The
data collection unit of the PAMS project at the CSSM became a separate unit, called Survey and
Behavioral Research Services (SBRS), during study implementation.

The PAMS project was based on several preliminary, prior studies by Matthew et al. (85,
87) and Calabro et al. (20). In the two studies by Matthew et al., the 24PAR method was found to
be valid relative to accelerometry-based activity monitors for adults. Calabro et al. (20)
compared the computerized 24PAR with the SWA and IDEEA (i.e. pattern-recognition
technology) in terms of estimating EE and MVPA in adults. They (20) found out that in
estimating EE, the 24PAR had high correlations (ranges from 0.89 to 0.90) and no significant
differences (p-value > 0.05) in relation to the SWA and IDEEA, even though relatively larger
measurement errors were identified for estimation of MVPA.
2.7.2 Sampling/Screening

A key goal of the project was to recruit a sample that was as representative as possible. It is not possible to recruit a sample that is representative of the country as a whole so PAMS sought to match demographics within the state of Iowa. The objective of sampling for the PAMS project was to recruit participants that are composed of 10% African American (i.e. referred to as Black hereafter) and 10% Hispanic, and living in both rural and urban areas in Iowa, using a stratified sampling technique. To satisfy this goal, four Iowa counties (i.e. Black Hawk, Dallas, Marshall, and Polk) were selected, since each of these four counties included a relatively large number of minorities (i.e. Black, Hispanic) and two of them were considered rural, with the other two being considered urban.

A sample of potential participants in the four Iowa counties was purchased from the Survey Sampling International, and was contacted through random digit dialing. The purchased sample included only telephone numbers; cell-phone numbers and addresses were not included. Screening of participants and administration of the 24PAR were both conducted over the phone with assistance from the Computer Assisted Telephone Interviewing (CATI) laboratory using Blaise software. Specific details and samples of the screening process are described in Appendix A. The eligibility criteria were adults 1) residing in one of the four selected counties, 2) aged 21-70yrs, 3) who were able to walk, and 4) who were able to perform a given set of paper surveys written in either English or Spanish. Participants that were in pregnancy, nursing babies and/or were equipped with a pacemaker and/or other electronic medical devices were not eligible for this study.

The objective of data collection was to collect a complete series of necessary data from a total of 1200 adults over a 2-year time span. The design called for data to be collected in 8
sequential, 3 month quarters to enable samples to be balanced over time to meet the targeted enrollment. In Quarter 1, a sample of 1,500 household telephone numbers was obtained to ensure that we could screen and enroll at least 150 participants per quarter. Recruitment procedures were refined and for each of the subsequent seven quarters (Quarters 2-8), 750 household telephone numbers were obtained, resulting in a total of household 6,750 telephone numbers (i.e. 1,500 + 750 × 7). Figure 3 describes specific details of data collection process, and shows how the initial sample of 6,750 was reduced to the final sample of 1,501. From the initial sample of 6,750 households, households were removed due to ‘not-in-service’ telephone numbers (n=784) and ‘non-households’ (n=53). Additional 2,691 households were removed since 1,755 of them refused screening, 51 were not responsive and 885 were not reached after the maximum number of calls (i.e. 20 times). Of 3,222 screened households, 1,079 did not meet the eligible criteria, while 2,143 were eligible for the PAMS project. Of the 2,143 households, 378 refused to participate in the project, 96 were not reached after maximum calls, and 21 were not available, leaving 1,648 participants who were eligible and agreed to participate in the project. This was equivalent of 24.4% of the initial sample of household telephone numbers obtained (i.e. 6,750). However, 147 of 1648 participants were removed for the following reasons: changing their mind about participating (n=141), death (n=1), relocation (n=3) and/or becoming pregnant (n=2). This resulted in a total of 1,501 participants (i.e. 22% of the initial sample) that were enrolled in the study.
Figure 4. A flow diagram of recruitment and enrollment of participants.
2.7.3 Data Collection

Each participant was asked to perform two sessions of data collection on two different randomly selected days, with at least 12 days apart from one another. In each of the two measurement sessions, each participant wore the SWA for 24 hours and completed the telephone-administered 24PAR next day recalling the previous day’s physical activities. A sample of the 24PAR is shown in Appendix B. To administer the two sessions of SWA measurement, staff members from the CSSM/SBRS had to visit each household twice. On the first visit, they obtained informed consent form, distributed the SWA to the participants after configuration, and measured height and weight. Participants were told to remove the SWA from their body only when showering, swimming and/or doing any aquatic activities. They were also asked to record any activities in the activity log that were performed when the SWA was not worn. During the second visit, the SWA was collected from the participants, and a monetary compensation was provided.

With the 24PAR, participants were asked to recall physical activities that they performed for at least 5 minutes in the previous day. The previous day recalled was divided into four 6-hour time windows (i.e. midnight to 6 am, 6 am to noon, noon to 6 pm, and 6 pm to midnight) in order to facilitate participants’ recall. Each reported activity type was matched to a reduced list of Compendium of Physical Activity (See Appendix C) in order to obtain a corresponding predicted MET code (indicating EE values). The original Compendium of Physical Activity was developed by Ainsworth et al. (5), but there were multiple activity codes indicating the identical activity type. Therefore, we simplified and reduced the original Compendium to have unique MET codes for the same type of activity. For instance, a single activity code of “sit, computer use” was used instead of using three related codes: work computer use, home computer use, and volunteer
computer use. In addition to recalling specific types of activities, participants reported corresponding minutes, location and purpose information of each activity. The sum of minutes across all activity codes for each person was checked to examine if it was equal to 1,440 minutes (i.e. 24hours). There were five location categories: Work/Volunteer, Home Indoors, Home Outdoors, Transportation, and Community, and six purpose categories: Work (paid job), Home & Family Care, Volunteering, Exercise/Sports (for fitness or for fun), Education (formal education, for work or a degree), and Leisure (discretionary time, not any of the other categories).

2.7.4 Data Management

As described above, a total of 1,501 participated in the study, resulting in a total of 2,981 cases (i.e. Trial 1: 1,501, and Trial 2: 1,480). However, 142 of the 2,981 cases were removed for the following reasons: Refusal to perform 24PAR (n=7), 24PAR data lost due to staff error (n=28), 24PAR not available due to medical surgery (n=1), unreachable by phone for 24PAR interview (n=5), SWA data lost during data transfer (n=10), SWA data lost due to staff error (n=1), no SWA data recorded (n=32), SWA data not processed (n=64), SWA not worn due to pregnancy (n=1), SWA data insufficient (n=1), and duplicated SWA data entry (n=2). This elimination process resulted in a total of 2,839 cases (i.e. Trial 1: 1,442 and Trial 2: 1,397) from 1,468 unique participants remaining in the final data set.

The final data set includes numerous variables, such as demographic (i.e. age, gender, height, weight, BMI, ethnicity, smoking status, etc.), socio-demographic (i.e. education background, income level, town size, marital status, etc.) variables, EE (i.e. MET, Kcal), activity time in different intensities (i.e. sedentary, light, moderate, vigorous intensity) and context
information (i.e. type, location, purpose) of activities. Survey weights were calculated using a customized jackknife procedure (53).

2.8 References


53. Fuller WA. *Sampling Statistics.* New York: Wiley; 2009; Section 4.2.2.


CHAPTER 3. THE ACCURACY OF THE 24-HOUR ACTIVITY RECALL METHOD FOR ASSESSING SEDENTARY BEHAVIOR

A paper to be submitted to *International Journal of Behavioral Nutrition and Physical Activity*

Youngwon Kim, Gregory J. Welk

3.1 Abstract

Purpose: Sedentary behavior (SB) has emerged as a modifiable risk factor for various health outcomes, but little is known about the measure errors associated with estimates of SB. The purpose of this study was to determine the validity of the 24-hour Physical Activity Recall (24PAR) relative to the SenseWear Armband (SWA) for evaluating three different definitions of SB. Method: Each participant (n=1485) was asked to undertake a series of data collection procedures on two randomly selected days, each of which consisted of wearing a SWA for a full day, and then completing the telephone administered 24PAR the following day to recall the past day’s activities. MET-derived criteria (≤1.5) were used to obtain Total Sedentary Time (TST). Estimates of sleep and lying down time were subtracted from TST to produce Non-sleep Sedentary Time (NSST) and Non-sleep Non-Lying down Sedentary Time (NSNLST). Results: Analyses based on 95% equivalence testing demonstrated that the 24PAR provided significantly equivalent estimates only for TST (90% confidence interval: 920.2 and 935.6 min/d) relative to the SWA values (zone of equivalence: 913.9 and 1117.0 min/d). Larger MAPE values were identified for NSST (35.1%) and NSNLST (36.7%) than for TST (18.1%). Bland-Altman plots indicated individuals with extremely low or high levels of sedentary time provided relatively comparable sedentary time estimates between the 24PAR and SWA. Overweight/obese (BMI≥25) and/or older (ages≥50yrs) individuals were more likely to under-estimate sedentary
time in comparison with normal weight and/or younger individuals. Conclusion: The 24PAR yielded relatively small measurement errors for TST, but large measurement errors for NSST and NSNLST. The magnitude of measurement errors varied by the level of overall sedentary time and demographic indicators. Evidence from this research informs future work designed to develop measurement error models to correct for various sources of errors inherent in the 24PAR.

3.2 Introduction

Sedentary behavior (SB) has emerged as a modifiable risk factor for mortality and cardiometabolic diseases, independent of accumulation of physical activity (PA) (24). Evidence indicates that contemporary adults are known to spend more than half of their waking hours being sedentary (21). However, different patterns of disparities in sedentary time among various adult populations are likely to be observed depending upon the choice of measurement tools (subjective versus objective) (14). This is mainly attributable to the different magnitude and distributions of measurement errors associated with the subjective and objective measurement tools. Research in this area is further compounded by the different ways to conceptualize SB and by differential influences of social/demographic characteristics on objective and subjective tools. To advance research on SB, it is important to better understand the underlying nature and magnitude of measurement errors, and their interplay with different definitions of SB and socio-demographic indicators.

Efforts have been made to improve the accuracy and utility of measurement tools for assessing SB, but a key gap in SB research is the lack of consensus on the definition of SB (13). This makes it particularly challenging to properly assess SB and to compare prevalence and
effects of SB across different studies. For example, a seminal paper by Pate et al. (25) originally defined SB as any activities inducing energy expenditure (EE) not substantially higher than resting EE (usually defined as ≤1.5MET). However, this definition does not take into account the behavioral posture of SB, and can potentially include time spent sleeping. Some studies have examined SB in terms of the postural characteristics of SB, such as time spent sitting (18), while other studies have incorporated behavioral indicators such as screen time (7), TV viewing (8), and/or computer use (10). Concerted efforts have been made in recent years to establish consensus definitions of SB to help standardize research. The Sedentary Behaviour Research Network (SBRN), for example, has specifically proposed a definition of SB “as any waking behavior characterized by an energy expenditure $1.5 \leq$METs while in a sitting or reclining posture” (4). This SBRN definition specifically excludes any activities that are performed while sleeping and/or lying down in order to more directly target sitting time as the predominant component. To date, few studies have directly compared estimates based on different conceptualizations of SB.

A wide variety of objective and subjective measurement tools are available to assess SB but additional considerations are needed to produce estimates that exclude sitting and lying time. For example, objective monitors (i.e. accelerometers, inclinometers) can provide reasonably accurate estimates of METs but most do not provide direct estimates of sitting or lying. Subjective measurement tools (i.e. recalls, questionnaires) can provide contextual information about behavior but are more susceptible to measurement errors due to recall bias (9), social desirability and social approval bias (1). Previous research (3, 6) has specifically documented the inherent limitations of longer-term recall instruments but short-term recall methods, such as 24-hour Physical Activity Recall (24PAR), have shown promise for minimizing measurement errors
in assessing PA and SB (23, 27). Because recall of the past 24-hour period is fairly robust, the 24PAR is able to capture detailed behavioral patterns of SB and differentiate the behavioral postures needed to compute various definitions of SB (i.e. sleeping, lying, and sitting). The 24PAR has promise for advancing research on SB but estimates must be compared against objective measures to evaluate validity.

The Physical Activity Measurement Survey (PAMS) is a population-level study designed to understand measurement errors in self-report measures of PA but the design and measures also offer considerable potential to advance research on SB. Participants wore a SenseWear Armband (SWA) monitor for a 24-hour period and completed a detailed recall of behavior using an interviewer-administered 24PAR protocol. The use of both the subjective and objective measures is consistent with best practices in epidemiology research (14, 28) since it provides a more comprehensive evaluation of behavior. A previous study (29) using the PAMS data validated the 24PAR method against the SWA for PA but it is important to also examine the accuracy of the 24PAR for estimating SB. Therefore, the purpose of this study was to investigate the validity of the 24PAR tool relative to the SWA for assessing SB with the representative sample of adults from the PAMS project.

3.3 Method

3.3.1 Sample

The PAMS study used a multi-level stratified sampling strategy to obtain a representative sample of Iowa adults ages 20-75yrs. Potential participants were contacted through random digit dialing with a sample pool purchased from Survey Sampling International. The inclusion criteria were adults that aged 20-75yrs, able to walk, and able to complete both a telephone and written
paper survey in either English or Spanish. Any participants with medical conditions (i.e.,
allergies to the metal part of the armband monitor) preventing them from participation were
excluded. The PAMS project was approved by the local Institutional Review Board. All
participants signed written informed consent before participation.

3.3.2 Instruments

24 Physical Activity Recall (24PAR): The 24PAR is a telephone- and interviewer-
administered self-report tool designed to provide detailed information about activity time, energy
expenditure, and specific context of SB and PA performed in the past day. With the 24PAR,
participants are asked to report on activities of the past day in minimum bouts of 5 minutes
across three distinct time windows (morning, afternoon and evening). Each reported activity was
matched with a corresponding MET score from the refined Compendium of PA (2).

SenseWear Armband Mini (SWA): The SWA (BodyMedia, Inc., Pittsburgh, PA) is a
non-invasive, multi-sensor activity monitor designed to be worn on the triceps of an upper arm.
It relies on various physiological sensors (heat flux, galvanic skin response, skin temperature,
near body temperature) as well as a tri-axial accelerometer. Resulting parameters (i.e. activity
time, MET, speed/distance, etc.) are produced using a manufacturer’s proprietary algorithm
based on the composite values of the sensors and tri-axial accelerometer. Previous validation
studies (11, 16, 20) have demonstrated the high accuracy of the SWA for estimating energy
expenditure and activity time for adults. Moreover, a critical strength of the SWA is the ability of
the SWA to correctly identify non-wear time (vs. wear time), which makes it particularly useful
for field-based surveillance and/or intervention research. Given these strengths, the SWA served
as a criterion method to determine the validity of the 24PAR herein. The latest version of
Software v8.0 (coupled with algorithms v5.2) was used to process the SWA data.
3.3.3 Data Collection

Each participant was asked to undertake two separate sessions of the measurement protocol (referred to as Trial 1 and Trial 2 hereafter). Each measurement protocol was composed of wearing the SWA for a full 24 hours on a randomly selected day and completing a 24PAR the next day recalling activities performed in the past day (same as the day for SWA monitoring). Staff members visited each participant’s house one day prior to the monitoring day in order to distribute a SWA monitor and provide instructions on the appropriate use of it. Staff members made a follow-up visit (i.e. one day after the monitoring day) to the participant’s house to collect and download the SWA as well as schedule the second 24PAR/SWA session (i.e. Trial 2). A team of trained interviewers utilized a computer-assisted telephone interview (CATI) system programmed using the Blaise Trigram methodology to carry out a 24PAR interview over the telephone. Each participant was asked to report on the types, minutes, purpose and location of activities that they performed in the past day, the same day as the SWA monitoring day. The interviewers tracked total reported minutes to ensure that the sum of the reported minutes is 1,440 (i.e. 60min×24h). It took an average of 20min (range from 12 to 45min) to complete a single 24PAR interview. The data were collected across 8 3-month quarters over a 2-year time span. More detailed descriptions of the study design and data collection procedure are described elsewhere (29).

3.3.4 Data Processing

Minutes reported from the 24PAR were aggregated up for each reported activity for each participant. Corresponding MET scores (assigned from the reduced set of PA Compendium) were used to categorize each reported activity as sedentary (MET≤1.5) versus non-sedentary activity (MET>1.5). All minutes with MET≤1.5 were summed up for each participant to provide
an overall estimate of Total Sedentary Time (TST). Time spent sleeping was obtained from the reported minutes for an activity code called ‘Sleep and nap’ while time spent lying was computed as the sum from four different codes (‘lying down talking’, ‘lying down playing computer games’, ‘lying down quietly awake’ and ‘lying down watching TV/reading’). These estimates of sleep time and lying time enabled direct calculations of Non-Sleep Sedentary Time (NSST = TST – sleep time) and Non-Sleep, Non-Lying Sedentary Time (NSNLST = TST – sleep time – lying time).

Parallel calculations were conducted with the SWA. The SWA produces MET values for every minute so time spent with METs ≤1.5 were summed to estimate TST. Sleep time and lying down time for the SWA were directly obtained from the Bodymedia software and were subtracted from TST in similar ways to produce the corresponding estimates of NSST and NSNLST.

For participants that performed both Trial 1 and Trial 2, the values from the two trials were averaged for 24PAR and SWA. For participants with data from a single trial, the original values were used.

### 3.3.5 Statistical Analyses

The study examined factors influencing agreement between subjective and objective estimates of SB. The analyses adopted a similar equivalence testing methodology used in a previous PAMS paper to evaluate agreement on estimates of EE and PA (29). In this case, we used a weighted 95% equivalence test (11) and weighted correlation analyses to evaluate group-level agreement between the estimates of SB from the 24PAR and SWA. If a 90% confidence interval (CI) for the 24PAR is completely included within a specified equivalence zone (i.e. ±10% of the mean of the SWA), the 24PAR is considered to be significantly equivalent to the
SWA, on average. Greater detail about the equivalence testing method is provided elsewhere (19, 29). Individual-level agreement was evaluated using weighted mean absolute percent errors (MAPE) and Bland-Altman plots with 95% limits of agreement (LoA).

Weighted Analyses of Variance (ANOVA) were performed to examine the interaction effects among age, BMI and gender for differences in NSST between the 24PAR and SWA. Variables and interactions with significant beta coefficients (i.e. p-values < 0.05) were included in the model. The resulting interaction effects were illustrated on heat maps.

All analyses were adjusted to account for the sample weights. The survey weights were calculated with a customized jackknife procedure to estimate standard errors (12), and used to account for the complex sampling design of the PAMS project and to obtain population-level estimates. Data processing and management were performed in STATA/SE version 12 (StataCorp LP, College Station, TX). Equivalence testing and heat map analyses were performed in SAS (SAS Institute Inc, Cary, NC) and R, respectively.

3.4 Results

The PAMS study used a multi-level stratified sampling strategy to obtain a representative sample of Iowa adults ages 20-75yrs. Potential participants were contacted through random digit dialing with a sample pool purchased from Survey.

A final sample of 1,458 was included for analyses in this study. Of the 1,458 adults, 1,356 provided the 24PAR and SWA data for both Trial 1 and 2, and 102 provided the data only for one of the two trials (i.e. 71 with only Trial 1 and 31 with only Trial 2). Specific characteristics of the final sample of the participants are presented in Table 1.

Results from 95% equivalence testing revealed that the 90% CI (920.2 and 935.6 min/d) of the 24PAR completely fell within the equivalence zone (913.93 and 1117.03 min/d) defined
by the SWA in assessing TST. However, the 24PAR yielded substantial underestimation of NSST (90% CI: 443.0 and 457.6 min/d) and NSNLST (90% CI: 411.0 and 425.8 min/d), both of which led to insignificant equivalence relative to the SWA. (See Figure 1)

Significant moderate correlation coefficients were observed for TST (R=0.47), NSST (R=0.45) and NSNLST (R=0.45). Relatively larger MAPE values were identified for NSST (35.1%) and NSNLST (36.7%) than for TST (18.1%). (See Table 2)

Bland-Altman plot analyses revealed similar patterns of systematic bias for all the three definitions of SB. To be specific, “wide diamond” shapes were observed, which implies that individuals with extremely low or high levels of sedentary time provided comparable sedentary time estimates with the 24PAR in relation to the SWA. However, those that are moderately sedentary yielded large recall errors (primarily under-estimation) with the 24PAR. Corresponding 95% LoAs were -521.5 and 307.6 min/d for TST, -618.6 and 176.0 min/d for NSST, and -558.2 and 247.9 min/d for NSNLST, all of which are deemed very wide. (See Figure 2)

Figure 3 illustrates 3-way interaction effects of age, gender and BMI for differences in NSST on heat maps. White color indicates that the differences between the 24PAR and SWA are zero. Blue color indicates that values from the 24PAR are smaller than the SWA, and red color indicates that values from the 24PAR are larger than the SWA. The vast majority of the heat map areas were mostly depicted in blue, which indicates under-estimation of sedentary time by the 24PAR. More specifically, individuals that are considered overweight/obese (i.e. BMI>25) and/or relatively older (i.e. ages>50yrs) were more likely to under-estimate NSST in comparison with those that are normal weight and/or relatively younger. No gender effects were identified. (See Figure 3)
3.5 Discussion

Accurate assessment of SB is critical to advancing research on SB (26). Key priorities include a more thorough characterization of the magnitude, sources and distributions of measurement errors in estimates of SB. The inherent challenges of assessing SB with self-report methods are due, in large part, to the inconsistent quantification of SB and the inability to control for individual variability in perceptions and reporting of SB in the population. This study helps to fill this gap by capitalizing on a representative sample of adults to determine the patterns and distributions of measurement errors for the 24PAR relative to objective estimates from the SWA by age, gender and BMI.

There are no previous studies using this particular version of the 24PAR but insightful comparisons can be made with several past studies (5, 22, 29) that have adopted the basic 24PAR format. To be specific, Calabro et al. (5) examined the validity of the computerized 24PAR tool in relation to SenseWear Pro2 Armband monitors and IDEEA (i.e. pattern recognition technology) in a convenient sample of 20 adults. Overall, the 24PAR exhibited high accuracy for estimating total EE (correlations ranging from 0.89–0.91) but relatively low accuracy for assessing MVPA time (correlations ranging from 0.48–0.70), relative to both the Pro2 Armband and IDEEA. Similar patterns of results were observed from Welk et al. study (29) that the 24PAR yielded relatively small MAPEs for EE (ranges from 10.3% to 15%) and large MAPEs for MVPA (ranges from 68.6% to 269.5%). With respect to the accuracy of the 24PAR for assessment of SB (i.e. NSST), the current study is comparable with a previous study by Matthews et al. (22) that assessed NSST in a convenient sample of 88 adults. The agreement statistics from the current study (i.e. correlation of 0.45 and non-equivalent estimates of NSST) are similar to those from Matthews et al. study (i.e. correlations of 0.34 and 0.67 and significant
differences of NSST) (22). The two validation studies demonstrated the relatively poor overall validity of the 24PAR in estimating SB, but additional research is clearly needed to further investigate the accuracy of the 24PAR specific for assessment of SB in relation to a true gold standard method and under various environments.

The use of the PAMS data herein allowed for identifying the underlying patterns and distributions of measurement errors of the 24PAR in assessing SB at the population level. A notable pattern (detected from the Bland-Altman plots) is the tendency that individuals that were highly or minimally sedentary exhibited relatively smaller measurement errors with the 24PAR, in comparison with those that were moderately sedentary. This finding makes conceptual sense since it would be easier for an individual to correctly recall the previous day’s sedentary activities if the total amount of time spent sedentary was extremely large or small. Another interesting finding was the variation of measurement errors by age, gender and BMI (identified from the heat map analysis). To be specific, individuals that were older than 50yrs old and/or overweight/obese were more likely to under-estimate sedentary time in comparison with those that were younger than 50yrs old and/or normal weight. This result clearly confirms the known concept of relative intensity (15). For example, the study by Welk et al. (29) using the same PAMS data indicated that older and/or obese individuals were more likely to perceive a low intensity of activities as moderate or vigorous, given that they tended to have lower physical fitness. As a result of this, substantial overestimation of MVPA was observed in that study (29). Interestingly, the overestimation of MVPA by the older and/or obese individuals directly explains the underestimation of overall SB in the current study. The dependency of these reported estimates suggests the need to develop and calibrate separate measurement error models to correct for recall biases in the estimation of both MVPA and SB.
The current study is the first empirical research to validate a self-report tool for assessing different constructs of SB at the population level. The 24PAR and SWA provided equivalent estimates of TST, but substantially different estimates of NSST and NSNLST. This is mainly attributable to the difference between the 24PAR and SWA in estimates of sleep time (and lying down time). Supplemental Digital Content 1 clearly illustrates the different contribution of sleep, lying down and NSNLST to the TST for SWA and 24PAR; only a sub-sample of 840 participants that had no zero values for lying down time were included for this analysis. The NSNLST by the SWA and 24PAR was 404.6min/day and 545.4min/day, respectively, which was due, in large part, to the considerable difference for sleep time: 480.2min/day by SWA versus 369.2min/day by 24PAR. In the current study, sleep time for the SWA and 24PAR was obtained from the respective method, but there is no evidence as to which method is more accurate than the other in terms of sleep assessment. Future research is warranted to validate the SWA and 24PAR method for estimating sleep time and lying down time.

This study has some limitations. First of all, the SWA is nor capable of classifying standing activities, while the 24PAR does. Thus, we examined the three different types of SB definitions that do not incorporate standing in order to facilitate direct comparisons between the 24PAR and SWA. Time spent standing would further distinguish types of light activity that have been shown to have health benefits (17), but the SWA is not presently able to distinguish standing from sitting and/or walking. Another limitation is that the vast majority of the participants were White (88%), so the findings from this study might not be applicable to other ethnicities (i.e. Black, Hispanic, etc.). However, we employed a stratified sampling technique to recruit a representative adults, which made it possible to oversample the minority populations (11%).
3.6 Conclusion

The present study examined the agreement between the 24PAR and SWA for evaluating three definitions of SB and the influences of demographic indicators on the agreement. Overall, the 24PAR exhibited relatively good validity for estimating TST, but low validity for NSST and NSNLST estimates. The magnitude and distributions of measurement errors varied considerably by demographic indicators (particularly, age and BMI). Evidence obtained herein provides unique insights about the underlying nature of measurement errors for assessment of SB. This research can serve as a fundamental framework for future work to establish measurement error models for minimizing errors inherent in the 24PAR.

3.7 Acknowledgment

We thank all the participants for the participation in the study. This study was supported by the National Institute of Health grant (R01 HL91024-01A1).

3.8 References


List of tables/ figures/ Supplemental Digital Content

Table 1. Characteristics (mean, proportion, and standard error) of the participants included.

Table 2. Indicators for agreement between 24-hour physical activity recall (24PAR) and SenseWear Armband (SWA) monitor

Figure 1. Results from 95% equivalence testing for agreement between the 24-hour Physical Activity Recall (24PAR) and SenseWear Armband (SWA) for Total Sedentary Time (TST; top panel), Non-Sleep Sedentary Time (NSST; middle panel), and Non-Sleep Non-Lying Down Sedentary Time (NSNLST; bottom panel). Note: Thick solid lines indicate 90% confidence intervals for the 24PAR, and double dotted lines indicate equivalence zones defined by the SWA. An asterisk (*) indicates significant equivalence.

Figure 2. Bland-Altman plots with 95% limits of agreement for (A) total sedentary time, (B) non-sleep sedentary time and (C) non-sleep non-lying down sedentary time.

Figure 3. Heat maps for 3-way interaction effects on differences in non-sleep sedentary time between 24-hour physical activity recall (24PAR) and SenseWear Armband (SWA). Note: White area indicates no difference between the 24PAR and SWA. Blue and red area indicate under- and over-estimation of sedentary time, respectively, by the 24PAR relative to the SWA.

Supplemental Digital Content 1. Relative contributions of Non-sleep Non-Lying down Sedentary Time (NSNLST), lying down time and sleep time to Total Sedentary Time (TST) for 24-hour Physical Activity Recall (24PAR) and SenseWear Armband (SWA).
Table 1. Characteristics (mean, proportion, and standard error) of the participants included.

<table>
<thead>
<tr>
<th>Variables</th>
<th>All (n=1458)</th>
<th>Female (50.5% (1.8))</th>
<th>Male (49.5% (1.8))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (yrs)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-29 yrs, %</td>
<td>8.3 (1.0)</td>
<td>7.5 (1.5)</td>
<td>9.2 (1.5)</td>
</tr>
<tr>
<td>30-39 yrs, %</td>
<td>22.7 (1.7)</td>
<td>19.3 (2.2)</td>
<td>26.2 (2.5)</td>
</tr>
<tr>
<td>40-49 yrs, %</td>
<td>33.7 (1.8)</td>
<td>37.3 (2.6)</td>
<td>30.1 (2.5)</td>
</tr>
<tr>
<td>50-71 yrs, %</td>
<td>35.2 (1.5)</td>
<td>36.0 (2.1)</td>
<td>34.4 (2.3)</td>
</tr>
<tr>
<td><strong>Body Mass Index (BMI)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight, %</td>
<td>24.7 (1.6)</td>
<td>30.4 (2.4)</td>
<td>18.9 (2.0)</td>
</tr>
<tr>
<td>Overweight, %</td>
<td>32.9 (1.7)</td>
<td>30.4 (2.3)</td>
<td>35.4 (2.5)</td>
</tr>
<tr>
<td>Obese, %</td>
<td>42.4 (1.8)</td>
<td>39.2 (2.4)</td>
<td>45.7 (2.6)</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White, %</td>
<td>88.5 (1.3)</td>
<td>88.8 (0.2)</td>
<td>88.1 (1.9)</td>
</tr>
<tr>
<td>Black, %</td>
<td>7.1 (1.0)</td>
<td>8.0 (1.4)</td>
<td>6.1 (1.2)</td>
</tr>
<tr>
<td>Others, %</td>
<td>4.5 (1.0)</td>
<td>3.1 (1.1)</td>
<td>5.8 (1.6)</td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school, %</td>
<td>3.1 (0.6)</td>
<td>3.9 (1.1)</td>
<td>2.3 (0.6)</td>
</tr>
<tr>
<td>High school diploma/some college, %</td>
<td>50.2 (1.8)</td>
<td>50.0 (2.5)</td>
<td>50.4 (2.6)</td>
</tr>
<tr>
<td>College/graduate school, %</td>
<td>46.7 (1.8)</td>
<td>46.1 (2.5)</td>
<td>47.3 (2.6)</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than $25,000, %</td>
<td>13.7 (1.1)</td>
<td>15.6 (1.6)</td>
<td>11.9 (1.7)</td>
</tr>
<tr>
<td>From $25,000 up to $75,000, %</td>
<td>43.9 (1.8)</td>
<td>48.1 (2.6)</td>
<td>39.6 (2.5)</td>
</tr>
<tr>
<td>More than $75,000, %</td>
<td>42.4 (1.9)</td>
<td>36.3 (2.6)</td>
<td>48.5 (2.7)</td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full-time job, %</td>
<td>66.5 (1.6)</td>
<td>54.8 (2.5)</td>
<td>78.2 (2.0)</td>
</tr>
<tr>
<td>Part-time job, %</td>
<td>12.2 (1.2)</td>
<td>16.9 (1.9)</td>
<td>7.4 (1.5)</td>
</tr>
<tr>
<td>Others, %</td>
<td>21.3 (1.3)</td>
<td>28.2 (2.1)</td>
<td>14.4 (1.6)</td>
</tr>
</tbody>
</table>

Note: All values were weighted to account for the complex sampling design. Values in parenthesis represent standard errors unless otherwise indicated. “Others” for Employment includes ‘Unemployed/ Retired/ Full-time homemaker or something else’
Table 2. Indicators for agreement between 24-hour physical activity recall (24PAR) and SenseWear Armband (SWA) monitor

<table>
<thead>
<tr>
<th>Definitions of sedentary behavior</th>
<th>Least Squares Means (Minute)</th>
<th>Correlations</th>
<th>MAPE, %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24PAR</td>
<td>SWA</td>
<td></td>
</tr>
<tr>
<td>Total Sedentary Time</td>
<td>927.9 (4.7)</td>
<td>1015.5 (5.4)</td>
<td>0.47* (0.04)</td>
</tr>
<tr>
<td>Non-Sleep Sedentary Time</td>
<td>450.3 (4.4)</td>
<td>654.3 (5.1)</td>
<td>0.45* (0.04)</td>
</tr>
<tr>
<td>Non-Sleep Non-Lying down Sedentary Time</td>
<td>418.4 (4.5)</td>
<td>553.9 (5.1)</td>
<td>0.45* (0.04)</td>
</tr>
</tbody>
</table>

Notes: values in parentheses are standard errors unless otherwise specified.

Abbreviations: 24PAR – 24-hour Physical Activity Recall; SWA – SenseWear Armband; MAPE – Mean Absolute Percent Error

* statistical significance (p-values less than 0.0001)

All values were estimated with the sampling weights applied.
Figure 1. Results from 95% equivalence testing for agreement between the 24-hour Physical Activity Recall (24PAR) and SenseWear Armband (SWA) for Total Sedentary Time (TST; top panel), Non-Sleep Sedentary Time (NSST; middle panel), and Non-Sleep Non-Lying Down Sedentary Time (NSNLST; bottom panel). Note: Thick solid lines indicate 90% confidence intervals for the 24PAR, and double dotted lines indicate equivalence zones defined by the SWA. An asterisk (*) indicates significant equivalence.
Figure 2. Bland-Altman plots with 95% limits of agreement for (A) total sedentary time, (B) non-sleep sedentary time and (C) non-sleep non-lying down sedentary time.
Figure 3. Heat maps for 3-way interaction effects on differences in non-sleep sedentary time between 24-hour physical activity recall (24PAR) and SenseWear Armband (SWA). Note: White area indicates no difference between the 24PAR and SWA. Blue and red area indicate under- and over-estimation of sedentary time, respectively, by the 24PAR relative to the SWA.
Supplemental Digital Content 1. Relative contributions of Non-sleep Non-Lying down Sedentary Time (NSNLST), lying down time and sleep time to Total Sedentary Time (TST) for 24-hour Physical Activity Recall (24PAR) and SenseWear Armband (SWA).
CHAPTER 4. CHARACTERIZING THE CONTEXT OF SEDENTARY LIFESTYLES IN A REPRESENTATIVE SAMPLE OF ADULTS: PHYSICAL ACTIVITY MEASUREMENT SURVEY (PAMS) PROJECT

A paper to be submitted to Journal of Physical Activity and Health

Youngwon Kim, Gregory J. Welk

4.1 Abstract

Background: Excessive time spent on sedentary behavior (SB) causes detrimental health effects, but little is known about the specific context of SB. The purpose of this study was to explore the most frequently occurring SBs, and location information of SB by socio-demographic indicators in adults. Methods: A representative sample of 1,442 adults (ages 20-71yrs) completed 24-hour activity recalls to provide information about time, types and location of the previous day’s activities. Reported activities were matched with MET scores from Compendium of Physical Activity. SB was defined as any activities with MET≤1.5. Results: Sitting was the most frequently reported SB, given that 15 of the 20 SBs involved a form of ‘sitting’. For the 5 location categories, the time allocations for Work, Home/Indoor, Home/Outdoor, Transportation, and Community were 27.5%, 20.5%, 15.8%, 11.3%, and 24.8%, respectively. Individuals with different socio-demographic indicators exhibited differential patterns of location of SB. Conclusion: The findings provide unique insights about the context of SB at the population level, and can serve as a guide for developing intervention/policy studies to reduce sedentary time and minimize disparities in SB.
4.2 Introduction

Evidence indicates that US adults, on average, spend 7.7 hours per day or 55% of their waking time being sedentary (17). Excessive time on sedentary behaviors (SB) is associated with adverse health outcomes, such as mortality rates (5, 18), obesity (6, 9), cardiovascular diseases (10), diabetes (7), and metabolic syndrome (8). In addition, substantial evidence (14, 22, 27) reveals that SB has detrimental effects on various health indicators, irrespective of accumulation of physical activity (PA). Current efforts by public health researchers have focused on ways to assess overall sedentary time (and relations to health outcomes); however, a fundamental gap in knowledge is the lack of understanding of the social and environmental context of SB in the population.

Several seminal studies have emphasized the necessity of understanding specific patterns of SB (20) and PA (12, 23) in order to develop more effective intervention strategies. Behavioral epidemiology frameworks specifically recommend the sequential collection of evidence to optimally inform the development of behavioral interventions (21). Keys in these models are to better understand the nature and context of the underlying behaviors. While considerable research has been performed to understand the context of PA (24, 25), relatively little is known about the context of SB. This lack of evidence on the contextual profiles of SB is due, in large part, to the inabilities of traditional measurement tools to assess context of SB (and PA) (13). To be specific, objective measurement tools (i.e. accelerometers and inclinometers) are capable of providing objective, accurate estimates of time spent sedentary, but cannot capture specific context (i.e. types and location). Subjective methods (i.e. self-reports) can provide contextual information of SB by asking respondents to recall or report habitual activities; however, they typically lack the precision to provide details on both the amount and context of SB.
The use of activity recall methods with relative shorter recall periods (i.e. previous 24-hours) has great potential to provide detailed characteristics about SB in adult populations (2). As a relatively short-term recall method, the 24-hour Physical Activity Recall (24PAR) can provide types, location and purpose of reported activities. While the 24PAR has been validated for assessing PA in adults (4, 26), only a single study (15) has been performed to evaluate its utility in characterizing the location and purpose information of SB with a very small number of adults (n=15). There has been no research to provide empirical investigations of contextual information of SB in a representative sample of adults and its variation by various socio-demographic variables. Therefore, the purposes of this study were 1) to explore the most frequently occurring sedentary activities and 2) to characterize the context information (i.e. types and location) of SB and its variation according to socio-demographic indicators in a representative sample of adults.

4.3 Method

4.3.1 Study Design

Data were collected part of a population-level cross-sectional measurement survey project, called Physical Activity Measurement Survey (PAMS), which collected replicate measures of both subjective (i.e. 24PAR) and objective (i.e. armband monitor) data. Potential participants (from four Iowa counties) were contacted through a random digit dialing (i.e. random selection) to obtain a representative sample of adults. The inclusion criteria of the PAMS project were any 20-75yrs old adults that could walk and perform recall interviews in either English or Spanish. Once recruited, participants completed two 24PAR interviews on randomly selected days (i.e. Trial 1 and Trial 2) to recall the specific activities performed on the previous
Data were collected and analyzed over a 2-year time span (i.e. 8 3-month quarters) between 2009 and 2011 to capture the inherent variability in behavioral patterns across seasons. Additional detail on the overall study design is provided elsewhere (26). This study was approved by the local Institutional Review Board and each participant signed informed consent prior to participation.

4.3.2 Instrument

The 24PAR is an innovative measurement tool designed to provide detailed insights about the context information of SB and PA as well as parameters of interest (i.e. activity time and energy expenditure). The 24PAR was administered over the telephone with assistance from the Computer Assisted Telephone Interviewing laboratory using Blaise software. With the 24PAR, respondents were asked to recall the previous day’s activities across four distinct time blocks (i.e. Midnight–6am, 6am–Noon, Noon–6pm and 6pm–Midnight) in episodes of at least 5 minutes. A notable feature of the 24PAR is its ability to provide information on purpose and location of reported activities. To be specific, each respondent was required to report why (i.e. purpose) and where (i.e. location) they performed each activity based on five purpose (e.g. Work, Home & Family, Leisure, Exercise/Sports, Other [i.e. combination of Leisure and Volunteer]) and five location (e.g. Work/Volunteer, Home – indoor, Home – outdoor, Transportation, and Community) codes. However, these categories were mainly developed to capture the context of “PA”. Thus, one of the purpose codes (i.e. Exercise/Sports) may be inappropriate for understanding the context of SB, so analyses were not performed for the purpose codes in the current study. Reported activities were matched with the reduced Compendium of PA (1) in order to assign corresponding metabolic equivalent (MET) scores to
each activity. The 24PAR has been shown to have high utility and validity in previous validation work (4, 26).

**4.3.3 Data Reduction**

The context and duration of the reported activities on the 24PAR were aggregated by day to create summary files that included a MET score and location code for each reported activity for each participant. The reported minutes were tabulated for each participant to ensure the total accumulated minute equals 1,440 (i.e. 60min×24h). For the present report, data were restricted to activities with MET scores≤1.5 (Based on Compendium of PA codes (1)) since this is the established criterion for SB (19). Activities with assigned MET scores>1.5 (i.e. light, moderate, and vigorous intensity) were excluded as were periods of reported sleeping and napping. The refined data were merged with participants’ demographic data based on participants’ ID. Socio-demographic variables in the dataset included gender (female and male), age group (20-29yrs, 30-39yrs, 40-49yrs, and 50-71yrs), weight status defined by BMI (normal weight, overweight and obese), ethnicity (White, Black, and Other), education background (less than high school, some college/post high school, and college/graduate), and income level (less than $25,000, from $25,000 up to $75,000, and more than $75,000). Data from Trial 2 and armband monitors were not used in the analyses.

**4.3.4 Statistical Analyses**

Time allocations across the five location codes were calculated. The rankings of the 20 frequently reported sedentary activities were determined on the basis of the number of participants that reported the activities at least once in a given day. Across all the top 20 most frequently occurring SBs, assigned MET scores and corresponding time allocations were also presented for each location category. Multiple one-way Analyses of Variance (ANOVA)
analyses with the Bonferonni adjustment (α=0.05) were performed to evaluate differences in time allocations between varying levels of each demographic variable across the five location codes. The Jackknife variance estimation method was used to calculate standard errors (11). Calculated sampling weights were applied to all analyses to account for the complex sampling methodology of the PAMS project. Data management and statistical analyses were performed in STATA/SE Version 12 for Windows (StataCorp LP, College Station, TX).

4.4 Results

A sample of 1648 participants in the PAMS project satisfied the eligibility criteria. However, 1501 participants remained in the final data set since 147 were excluded for the following reasons: choosing not to participate (n=141), death (n=1), relocation (n=3) and/or becoming pregnant (n=2). The sample of 1501 participants produced 2981 data cases. However, 149 observations were deleted for the following reasons: data entry errors with 24PAR (n=18), missing 24PAR data (n=13), outliers on 24PAR (n=7) or problematic data from armband monitors (n=111). The final reduced dataset of 2832 cases was obtained from a unique sample of 1468 participants (1442 from Trial 1 and 1397 from Trial 2), but the analysis for the current study was based on only 1442 participants (from Trial 1). Specific characteristics of the participants are summarized in Table 1. A total of 27 different types of sedentary activities were reported by the participants. The average self-reported sedentary time of the total population was 7.7 hours.

Figures 1 shows the top 20 most frequently reported sedentary activities along with corresponding time allocations across the 5 location categories, respectively. The most commonly reported sedentary activity was ‘sit eating’ (n = 1351), followed by ‘sit watching television’ (n = 1096), ‘sit computer use’ (n = 760) and ‘sit talking on phone’ (n = 760). Of the
20 sedentary activities, 15 (including ‘riding in a airplane, car, van, or truck’ and ‘riding a bus’) involved a form of ‘sitting’ in the definition. In regards to the location categories, the overall time allocations were 27.5% for Work, 20.5% for Home/Indoor, 15.8% for Home/Outdoor, 11.3% for Transportation, and 24.8% for Community. Time allocations for ‘sit eating’ and ‘Sit, watching television’ were relatively well-distributed for location categories. The third activity, ‘sit computer use’, however, occurred primarily at Work (61.9%) and Home/Indoor (23.2%). The majority of ‘sit talking on phone’ occurred at Home (41.1%), followed by Work (26.9%) and Community (23.7%).

Figures 2 shows time allocations of the 5 location categories by 6 different socio-demographic variables, respectively. To be specific, females reported significantly greater time spent being sedentary during transportation ($P=0.046$) and in the community ($P=0.021$) than males. Older individuals (ages 50-71yrs) reported significantly greater sedentary time at Home/Indoor ($P$ values ranging from <0.001 to 0.003), but less sedentary time at Work ($P=0.006$) and Community ($P=0.035$), compared with younger individuals. White people reported a significantly larger time allocation at Work ($P=0.003$) compared with Black people. Individuals with relatively higher education levels exhibited significantly larger sedentary time spent at Work ($Ps<0.001$), but smaller sedentary time at Home/Indoors and Outdoors ($Ps$ ranging from <0.001 to 0.003), compared with those with lower education levels. Individuals with higher income levels reported significantly larger sedentary time spent at Work ($Ps<0.001$), but less sedentary time at Home/Indoors ($Ps<0.001$) and Outdoors ($P=0.035$), in comparison with individuals with lower income levels.
4.5 Discussion

There has been considerable interest in understanding the specific context in which SB and PA occur (12, 23). Research on this topic, however, has been limited by the inability of traditional measurement tools (i.e. accelerometers, long-term recall methods) to capture contextual information. The PAMS study was designed specifically to address this gap and to improve the utility of self-report data for public health research. The established 24PAR protocol (16, 26) was refined to capture contextual variables, which enabled us to obtain detailed insights about the location of SB in a representative sample of adults. To be specific, the present study identified the top 20 most frequently reported SBs along with corresponding time allocations across the five different location categories.

A previous study by Tudor-Locke et al. (24) that examined SB (and PA) patterns from the American Time Use Survey (ATUS) reported similar rankings of predominant sedentary activities in a large population sample. For example, they reported the same general rankings for eating (Rank 1), TV viewing (Rank 2), and riding in a vehicle (Rank 4) as reported herein. The ATUS used a similar type of 24PAR (and the activities were also coded with the same Compendium codes), but a unique advantage of the present study is that we were able to provide insights about the location of the reported activities. We observed considerable variability in how the predominant activities were allocated across the 5 location categories. The patterns were somewhat different than those reported in a prior study by Keadle et al. (15) utilizing the traditional computerized version of the 24PAR (4). For example, the Keadle et al. study (15) found the Work/School category (130.7min) accounted for most of the total reported sedentary time, with substantially smaller sedentary minutes spent at Home (59.8min) and in the Community (39.5min). In the current study, we found 36% of total sedentary time to be
explained by the Home category, followed by 27.5% at Work, 24.8% in the Community and 11.3% during Transportation. The differential patterns of time allocations between this study and the Keadle et al. (15) study may be attributable to the difference in the location categories. However, the major difference is likely that the Keadle et al. study (15) used a convenient sample of 15 adults whereas the current study utilized a representative sample of over 1400 adults that were randomly selected through a multi-stage sampling procedure. The Keadle et al. study (15) provided evidence to support the validity of the reported 24PAR location (and purpose) codes so it was not designed with the same goal as the PAMS project.

A unique advantage of the present study is that it also demonstrates that individuals with different levels of socio-demographic indicators exhibited differential patterns of SB as well as different contextual explanations for where (i.e. location) the participants spent time sedentary. The findings, in general, yielded intuitive findings for comparisons across the 6 socio-demographic variables but some examples are noteworthy. For example, younger individuals (i.e. 20-29yrs) reported less sedentary time at ‘work’, but more sedentary time at ‘Home/Indoor’ compared with older individuals (40-49yrs). This may be because younger individuals may be less likely to be employed at sedentary jobs (compared with older adults). The larger allocation for the Home/Indoor category may reflect younger individuals’ greater interest in popular sedentary activities such as playing video games, using computers and/or watching TV, all of which are likely to occur at home. Similar comparisons were observed for the other socio-demographic indicators (i.e. Ethnicity, Education and Income). For example, individuals that are white or with higher levels of academic background (i.e. college graduates) and/or income (i.e. from $75,000 up to $100,000) reported being more sedentary ‘at work’ and less sedentary at home (compared with those that are black or with lower levels of academic background and/or
These findings clearly suggest that the appreciation of the specific context is critical for understanding the complex behavioral aspects of SB at the population level. Future population-level intervention and/or surveillance studies should employ context-specific approaches in order to reduce sedentary time and mitigate disparities of SB across various adult populations.

The current study is not without limitations. We used only a MET-derived criterion (≤1.5MET) to define SB, which is the same methodology used in the previous study by Tudor-Locke et al. (24). However, the definition of SB suggested by the Sedentary Behaviour Research Network (3) incorporates a posture component (i.e. sitting or reclining) in addition to the energy expenditure component (i.e. ≤1.5MET). By this definition, 4 of the top 20 sedentary activities (‘lying down, watching TV, reading’, ‘stand quietly, stand waiting in line’, ‘lying down quietly awake’ and ‘lying down, talking’) would not have been classified as SBs. However, the inclusion of these activities allowed for direct comparisons with other “traditional” forms of SB: ‘sit watching television’ and ‘sit reading ’ vs. ‘lying down, watching TV, reading’ and ‘sit talking on phone’ vs. ‘lying down, talking’. Another limitation is that the results from this study might not be generalizable to the entire US adult population, given that the participants were recruited from a single state of the US. However, the reported daily sedentary time (i.e. 7.7 hours/day) matched the national average of sedentary time (estimated by an objective monitor) in US adults (17). This may suggest that our sample shares similar characteristics with the whole US adult population. Moreover, the telephone-administered 24PAR used herein has not been directly validated for assessing context of SB. However, the previous validation study (26) found it to have acceptable agreement relative to an armband monitor in estimating energy expenditure. Moreover, context information captured by a computerized-24PAR (analogous to the telephone-
based 24PAR) was relatively comparable with context information measured by direct observation (15).

### 4.6 Conclusion

The present study provided comprehensive context information of SB (i.e. types and location) to advance understanding about SB in adults. Overall, most of the frequently reported SBs were in the form of “sitting”. Other prevalent sedentary activities were TV viewing, computer use and cell-phone use. Moreover, the patterns of sedentary time spent across the 5 location categories differed by various socio-demographic indicators. Evidence from this study can serve as a fundamental framework for designing and implementing future intervention studies aimed at reducing sedentary time at the population level.

### 4.7 Acknowledgment

Author affiliations: Department of Kinesiology, Iowa State University, Ames, Iowa (Youngwon Kim, Gregory J. Welk)

The PAMS project was supported by a grant from the National Institute of Health (R01 HL91024-01A1). However, the National Institute of Health did not play any role in designing, collecting, analyzing and/or interpreting the data collected from the PAMS project as well as in the writing and submission of this manuscript for publication. The authors made equal contributions to the present work. The authors declare that they have no competing interests.

### 4.8 References


Figure Titles

Figure 1. The top 20 most frequently reported sedentary activities and corresponding time allocations across the five location codes. (Work, Home/Indoor, Home/Outdoor, Transportation, and Community). All values were weighted to account for the complex sampling design.

Figure 2. Time allocations of five location codes (Work, Home/Indoor, Home/Outdoor, Transportation, and Community) across six socio-demographic variables. Note: Significant differences are indicated by combinations of ‘A’, ‘B’, and ‘C’. All values were weighted to account for the complex sampling design.
Table 1. Socio-demographic characteristics and reported sedentary time of the participants (n=1,442) included.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Values</th>
<th>Sedentary time, hours</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male, %</td>
<td>50.6 (1.8)</td>
<td>7.5 (0.2)</td>
</tr>
<tr>
<td>Female, %</td>
<td>49.3 (1.8)</td>
<td>7.8 (0.2)</td>
</tr>
<tr>
<td><strong>Age (yrs)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20-29 yrs, %</td>
<td>8.2 (1.0)</td>
<td>6.7 (0.5)</td>
</tr>
<tr>
<td>30-39 yrs, %</td>
<td>22.4 (1.7)</td>
<td>7.4 (0.3)</td>
</tr>
<tr>
<td>40-49 yrs, %</td>
<td>34.5 (1.8)</td>
<td>7.7 (0.2)</td>
</tr>
<tr>
<td>50-71 yrs, %</td>
<td>35.0 (1.5)</td>
<td>8.0 (0.1)</td>
</tr>
<tr>
<td><strong>Body Mass Index (BMI)</strong></td>
<td>29.9 (0.3)</td>
<td></td>
</tr>
<tr>
<td>Normal Weight, %</td>
<td>25.2 (1.6)</td>
<td>7.7 (0.3)</td>
</tr>
<tr>
<td>Overweight, %</td>
<td>32.6 (1.7)</td>
<td>7.7 (0.2)</td>
</tr>
<tr>
<td>Obese, %</td>
<td>42.2 (1.8)</td>
<td>7.7 (0.2)</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White, %</td>
<td>88.6 (1.3)</td>
<td>7.7 (0.1)</td>
</tr>
<tr>
<td>Black, %</td>
<td>6.9 (0.9)</td>
<td>8.0 (0.6)</td>
</tr>
<tr>
<td>Other, %</td>
<td>4.5 (1.0)</td>
<td>6.9 (0.8)</td>
</tr>
<tr>
<td><strong>Education Background</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school, %</td>
<td>3.1 (0.6)</td>
<td>6.6 (0.7)</td>
</tr>
<tr>
<td>High school diploma/some college,</td>
<td>50.1 (1.8)</td>
<td>7.4 (0.2)</td>
</tr>
<tr>
<td>College/graduate school, %</td>
<td>46.8 (1.8)</td>
<td>8.1 (0.2)</td>
</tr>
<tr>
<td><strong>Income Level</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than $25,000, %</td>
<td>13.5 (1.1)</td>
<td>7.8 (0.3)</td>
</tr>
<tr>
<td>From $25,000 up to $75,000, %</td>
<td>43.8 (1.8)</td>
<td>7.2 (0.2)</td>
</tr>
<tr>
<td>More than $75,000, %</td>
<td>42.7 (1.9)</td>
<td>8.1 (0.2)</td>
</tr>
</tbody>
</table>

Note: All values were weighted to account for the complex sampling design. Values in parenthesis represent standard errors unless otherwise indicated.
Figure 1. The top 20 most frequently reported sedentary activities and corresponding time allocations across the five location codes. (Work, Home/Indoor, Home/Outdoor, Transportation, and Community). All values were weighted to account for the complex sampling design.
Figure 2. Time allocations of five location codes (Work, Home/Indoor, Home/Outdoor, Transportation, and Community) across six socio-demographic variables. Note: Significant differences are indicated by combinations of ‘A’, ‘B’, and ‘C’. All values were weighted to account for the complex sampling design.
CHAPTER 5. INDEPENDENT AND JOINT ASSOCIATIONS OF SEDENTARY BEHAVIOR AND MODERATE-TO-VIGOROUS PHYSICAL ACTIVITY WITH OBESITY: COMPARISON BETWEEN SUBJECTIVE AND OBJECTIVE MEASUREMENT TOOL.

A paper to be submitted to *International Journal of Obesity*

Youngwon Kim, Duck-Chul Lee, Gregory J. Welk

5.1 Abstract

Objectives: The purposes of this study were to determine the independent and joint associations of sedentary behavior (SB) and moderate-to-vigorous physical activity (MVPA) with obesity, and to compare the associations between a subjective (24-hour Physical Activity Recall; 24PAR) and an objective (SenseWear Armband; SWA) method in a representative sample of adults. Method: Data were from the Physical Activity Measurement Study (PAMS), a survey of physical activity behaviors conducted on a representative sample of Iowan adults over a 2 year period. Each participant (n=1307) wore a SWA for a randomly selected day, and completed a telephone-administered 24PAR the following day to recall the previous day’s activities. Participants were classified into tertiles of SB and MVPA to examine associations with obesity. Results: Approximately 45% of the sample was obese. For the SWA outcomes, the odds ratios (95% confidence interval) of obesity were 2.89 (2.03-4.11) and 7.41 (4.89-11.22) for the medium and most sedentary group, respectively, when compared with the least sedentary group (after adjusting for MVPA). For the 24PAR, no significant associations were observed for SB, but a significant odds ratio of 0.67 (0.49-0.91) was observed for the high MVPA group. Joint
analyses with the SWA and 24PAR both revealed that individuals with higher SB and lower MVPA had greater odds of obesity than those with lower SB and higher MVPA. Conclusion: Objectively assessed SB and MVPA were positively and negatively associated with obesity, respectively, independent of each other. The null associations of SB and weaker associations of MVPA by the 24PAR may be attributable to larger measurement errors since the outcome measures were reported similarly and were captured on the same days. Future research is required to correct for measurement errors associated with self-report methods to determine the true relationships between SB, MVPA and obesity.

5.2 Introduction

Nearly one in every three US adults is considered obese (10), and the prevalence is expected to increase up to over 50% over the next two decades (45). The corresponding medical cost to treat obesity-related diseases during the same time period is estimated to be $48-66 billion (44). While numerous factors have contributed to the obesity epidemic, a key determinant may be the rapid societal/environmental changes from physically active lifestyles to sedentary lifestyles. This transition has been attributed, in large part, to the dramatic changes in technology, the increased reliance on motor vehicles, and the reduced activity involved in contemporary office work (20, 34).

Evidence indicates that on average, US adults spend about 7.7 hours/day on sedentary behavior (SB), which is equivalent to approximately 55% of the waking hours/day (29). Excessive time spent being sedentary has been shown to have detrimental effects on cancer, cardiovascular diseases and mortality in adults, irrespective of the accumulation of moderate-to-vigorous physical activity (MVPA) (4). However, the nature of these relationships may vary by
individual factors such as age, gender, ethnicity, socio-economic status, fitness and fatness. Numerous studies have shown that obese adults tend to spend more time being sedentary and less time being physically active time than normal weight or overweight adults (38, 43). However, recent studies have shown that excessive sedentary time is more deleterious for obese individuals than for non-obese individuals in the risk of developing cardiovascular diseases and type II diabetes (33). This hints at the complex etiology underlying the health effects of SB on obesity. Research on SB is still in relatively early phases of development and a key limitation is lack of consensus on the best ways to quantify and assess SB (13).

To date, most large observational studies to identify associations have used subjective measurement tools (i.e. self-report), which are more susceptible to measurement errors than objective tools (i.e. accelerometer). The influence of selecting a measurement type – either objective or subjective – on surveillance of SB and physical activity (PA) has been well-documented. For instance, PA surveillance research found that the proportion of US adults meeting the PA guidelines was over 50% by self-report, but only less than 5% via accelerometry (42). A surveillance report on SB from previous research identified significant differences in sedentary time across various demographic groups using different methods between men and women (15). In addition, a few previous studies have specifically examined the effects of using subjective versus objective methods on identifying associations between SB and obesity indicators (6, 28, 39). However, inconsistent findings were observed from the studies. For example, stronger associations were identified with accelerometer-determined objective measures for Chilean (6) and US adults (28), but with self-reported subjective measures for UK adults (39). All the studies (6, 28, 39) used traditional count-based methods for processing
accelerometer data, which is deemed inappropriate for assessing SB (2). Moreover, the previous studies (6, 28, 39) utilized traditional subjective methods requiring long-term recalls that are known to have greater measurement errors than short-term recall methods (31). The types of measures being compared and the sophistication of the data processing methods can influence outcomes so additional research is needed to better understand the relationships between SB and obesity.

Another important consideration for SB research is to understand the unique biological associations of various forms of sedentary activities with obesity. For example, one can spend much time watching TV, but little time using computer. Moreover, TV viewing may accompany other types of unhealthy behaviors (i.e. consumption of unhealthy snacks, drinking alcohol), but computer use may not. Different types of sedentary activities have been known to have considerably varying levels of associations with mortality rates (7, 24) and cardiometabolic diseases (11). However, only a few studies have been conducted to examine the effects of various types of specific sedentary activities (i.e. total sedentary time, sitting, screen time, TV viewing, computer use, reading, playing games, etc.) as well as their interactions with MVPA in relation to obesity measures (8, 19, 41).

A critical limitation in many studies is the use of a single measurement tool (either subjective or objective) to evaluate SB. To advance research it is important to understand the degree to which the choice of measurement tools influences the interplay of SB and MVPA in relation to obesity at the population level. Therefore, the purposes of this study were 1) to determine the independent and joint associations of SB and MVPA with obesity, and 2) to
evaluate whether or not the identified associations vary by the type of measurement tools in a representative sample of adults.

5.3 Method

5.3.1 Study Design

This research is an ancillary study of a cross-sectional measurement survey project, called Physical Activity Measurement Survey (PAMS), designed to develop measurement error models for a self-report tool. The PAMS project used a SenseWear Armband (SWA) Mini monitor and 24-hour Physical Activity Recall (24PAR) to provide objective and subjective indicators of activity, respectively. Participants wore the SWA for 24-hours on a randomly selected day, and performed a 24PAR measure the following day to recall and report on activities performed in the previous day (i.e. the same day as the SWA monitoring day). To facilitate the data collection procedure, a field staff member was sent to each participant’s home (the day before the SWA monitoring day) to provide detailed descriptions of the PAMS protocol, and distribute a SWA monitor along with instructions on how to use it. The staff also provided each participant an activity log to record any activities performed while the SWA was not worn. A follow-up visit to the participant’s home occurred the day after the monitoring day in order for the field staff to collect the SWA monitor used. Participants completed a second trial on another randomly selected day (i.e. at least 12 days after the first measurement trial) to obtain replicate measures from both the SWA and 24PAR. The data collection for the PAMS project was carried out across 8 consecutive, 3-month quarters (i.e. 2 years) to capture seasonal and weather variations. The study protocol of the PAMS project was approved by the local Institutional
Review Board and described in greater detail elsewhere (46). Each participant provided signed written informed consent prior to participation.

5.3.2 Participants

The PAMS project employed a multi-level stratified sampling technique to recruit a representative sample of adults across four counties (2 rural and 2 urban) in Iowa, USA. Adults included in a purchased sample pool from Survey Sampling International were contacted via random digit dialing. The inclusion criteria were adults aged between 20-75 years old, and capable of walking and completing surveys either in English or Spanish. The exclusion criteria were adults with any critical medical conditions preventing them from engaging in lifestyle activities.

5.3.3 Instrument

Two promising measurement tools were used to obtain both objective and subjective measures of SB and PA. Specific descriptions of the tools are provided below:

The SenseWear Armband Mini (SWA): The SWA (BodyMedia, Inc., Pittsburgh, PA) is a non-invasive pattern-recognition monitoring tool that utilizes multiple sensors (heat flux, galvanic skin response, skin temperature, near body temperature) as well as a tri-axial accelerometer. The SWA provides a variety of activity parameters (i.e. activity time, MET, Kcal, speed, and distance) for every minute. The high validity of the SWA for adult populations has been demonstrated in previous validation studies (12, 22, 27). Two particularly unique features of the SWA are the abilities to precisely detect non-wear time (versus wear time), and to collect data for extended periods of time (i.e. memory capacity of about 28 days and battery power of about 7 days), both of which make the tool very promising for field-based surveillance studies.
Data from the SWA were processed using the latest version of Software v8.0 (coupled with the proprietary algorithms v5.2).

The 24 Physical Activity Recall (24PAR): The 24PAR is a self-report measurement tool designed to assess activity time, energy expenditure and context of activities performed in the previous day. The 24PAR was administered over the telephone by trained interviewers using a computer-assisted telephone interview (CATI) system programmed with the Blaise software. The 24PAR interview requires each participant to report on the past day’s activities in episodes of at least 5 minutes. Participant were also asked to recall the specific context (i.e. location and purpose) of each reported activity. The 24PAR has been validated for assessing activity time and energy expenditure (5, 30, 46) as well as location and purpose of activities (23).

5.3.4 Data Processing

Upon completion of the SWA monitoring protocol, the SWA data were downloaded using the proprietary algorithms/software. The SWA provides MET values for every minute, so the standard MET-derived criteria were applied to classify each minute into different intensity categories: ≤1.5MET for SB, 1.5<MET<3.0 for light PA, and ≥3.0MET for MVPA. Classified minutes were aggregated to obtain total daily activity minutes of the respective intensities. SWA-determined sleep time was subtracted from the total categorized sedentary time to produce Total Sedentary Time (TST) for the SWA. We used a reduced listing of the PA Compendium (1), which consisted of a total of 270 activity codes, in order to assign predicted MET values to each reported activity from the 24PAR. We also used the same MET criteria (as for SWA) for the 24PAR data to classify each reported activity into the different intensities. A total of 27 reported activities were categorized as SB. TST for the 24PAR was obtained by subtracting reported sleep
time from the sum of all minutes reported for the 27 sedentary activities. Sitting time was obtained by summing up the minutes reported for 16 activities that included sitting in the definition. Screen time was the sum of the minutes from 7 screen-based activities; computer use from 3 activities, TV viewing from 2 activities and cell-phone use from 2 activities.

5.3.5 Variables

TST and MVPA were obtained from both the SWA and 24PAR. Time for the five individual sedentary activities (i.e. sitting, screen time, computer use, TV viewing and cell-phone use) was obtained only from the 24PAR. TST, MVPA and individual sedentary activities were each classified into tertiles (i.e. Low, Medium, High). Body Mass Index (BMI) was calculated as weight (kg)/ height squared (m²). Individuals with BMI ≥30 and BMI <30 were classified as obese and non-obese, respectively. The following 9 variables were included as covariates in the statistical models to determine the relationships of SB and MVPA with obesity: gender (i.e. male and female), age (years), ethnicity (i.e. White, Black, and Other), annual income (i.e. <$25,000/yr, between $25,000 and $75,000/yr, >$75,000/yr), employment (i.e. full time, part time, and unemployed/retired/full time homemaker), education background (i.e. less than high school, some college/post high school, and college/graduate), marital status (i.e. married/living as married, divorced/separated/widowed, and single/never married), current smoking status (i.e. smoker and non-smoker), and measurement day of week (i.e. weekday and weekend day).

5.3.6 Statistical Analyses

Descriptive statistics were carried out to summarize the demographic profiles, sedentary time and activity levels of the participants. Multiple logistic regression analyses were performed to investigate the associations of SB indicators and MVPA with obesity. Odds Ratios (OR) along
with 95% confidence intervals (CI) were used to investigate the associations of SB (including TST and 5 specific sedentary activities) and MVPA with obesity. Analyses were adjusted for the 9 confounders listed above (Model 1), and additionally TST and MVPA for each other (i.e. Model 2). In the full model (i.e. Model 2) for the 5 individual sedentary activities, all the 5 activities (in addition to subjectively estimated MVPA) were used as covariates. Stratified logistic regression analyses were also carried out to determine the associations between TST, MVPA and obesity. For instance, the analyses to examine the associations of TST with obesity were done separately for each of the three MVPA groups, and the analyses for MVPA were conducted separately within each of the three TST groups. No interaction effects between gender and TST or MVPA on obesity were detected in the full regression models and gender stratified analyses, so analyses were performed only for the whole sample. All statistical analyses were performed in STATA/SE Version 12 (StataCorp LP, College Station, TX).

5.4. Results

Analyses were performed with the data from a total of 1307 adults enrolled in the PAMS project that did not have any missing variables. Table 1 summarizes the physical and socio-demographic characteristics of the non-obese and obese individuals. The number of obese individuals was 587 (44.9%). Average means of the key parameters of sedentary activities as assessed by the 24PAR and SWA are summarized in Table 2.

Table 3 presents ORs (95% CIs) of being obese when TST and MVPA were assessed by the 24PAR versus SWA. With the 24PAR, none of the comparisons for TST showed significant associations with obesity. However, the high MVPA group had about 33% lower odds of obesity (95%CI: 0.49-0.91) compared with the low MVPA group after adjusting for all confounders.
including TST. When examined separately, none of the 5 sedentary activities were significantly associated with obesity (i.e. data not presented) after adjusting for confounders and MVPA (as well as the four other sedentary activities). When TST and MVPA were objectively assessed by the SWA, the odds of being obese were 3 to 10 times higher for the medium (OR: 3.05; 95%CI: 2.24-4.16) and high (OR: 10.11; 95%CI: 7.23-14.14) TST groups, respectively (Model 1). The associations for medium (OR: 2.89; 95%CI: 2.03-4.11) and for high TST (OR: 7.41; 95%CI: 4.89-11.22), while slightly attenuated, were still strong after additionally adjusting for objectively assessed MVPA (Model 2). Compared with individuals in the low MVPA group, those in the medium (OR: 0.26; 95%CI: 0.19-0.35) and high (OR: 0.14; 95%CI: 0.10-0.20) MVPA groups exhibited more than 70% lower odds of being obese after adjusting for all potential confounders (Model 1). While slightly attenuated, the associations for medium (OR: 0.41; 95%CI: 0.30-0.57) and high (OR: 0.50; 95%CI: 0.33-0.78) MVPA remained significant when further adjusting for objectively assessed TST (Model 2).

For the stratified and joint association analyses, the medium and high groups of TST and MVPA were combined, resulting in a total of 4 combined groups to preserve adequate statistical power and simplify the complicated stratified/joint associations of SB and MVPA with obesity. This was based on the independent association analysis (Table 3) indicating clear patterns of associations (i.e. positive for TST and negative for MVPA) in the ORs of obesity. Table 4 shows no significant associations of subjectively assessed TST (stratified by subjectively assessed MVPA). The medium/high MVPA was significantly associated with 25% lower odds of obesity (OR: 0.75; 95%CI: 0.56-0.99) in the medium/high TST. By the SWA, relatively more consistent and stronger associations were found for TST (stratified by MVPA) than for MVPA (stratified by TST). Specifically, the medium/high TST groups in the medium/high MVPA (OR: 3.79;
95% CI: 2.75-5.22) and low MVPA (OR: 3.29; 95% CI: 1.30-8.35) had more than three times the larger odds of obesity compared with the low TST groups. Similarly, the medium/high MVPA groups in the low TST (OR: 0.28; 95% CI: 0.10-0.78) and medium/high TST (OR: 0.32; 95% CI: 0.23-0.44) exhibited approximately 70% lower odds of obesity compared with the low MVPA groups.

When TST and MVPA were subjectively assessed with the 24PAR (Figure 1; panel A), individuals in the medium/high TST and low MVPA group had 42% higher odds of being obese (OR: 1.42; 95% CI: 1.04-1.93) compared with the reference group of low TST and medium/high MVPA. The low TST and low MVPA group had a slightly higher OR (although not significant) compared with the medium/high TST and medium/high MVPA group. With the SWA (Figure 1; panel B), the medium/high TST group exhibited a substantially higher odds of obesity (OR: 11.47; 95% CI: 7.98-16.47) than the reference group. More interestingly, the OR for the medium/high TST and medium/high MVPA group (OR: 3.67; 95% CI: 2.68-5.01) was slightly greater than the OR for the low TST and low MVPA group (OR: 3.41; 95% CI: 1.34-8.69); both ORs were significant. In addition, when we used all 9 combination groups from 3 TST and 3 MVPA categories, we found similar trends for both the stratified and joint analyses.

5.5 Discussion

This study systematically investigated the independent and combined associations of TST and MVPA with obesity, and also determined whether the observed associations vary by the subjective versus objective measurement tool. When TST and MVPA were subjectively assessed by the 24PAR, only MVPA (not TST) had significant inverse associations with obesity (based on the independent/stratified analyses). This finding was in line with findings from prior cross-
sectional research that higher self-reported PA time was more important than lower self-reported SB in the prevention of overweight and/or obesity (3, 28). However, it is important to note that contrasting results were identified from other cross-sectional studies that showed that reported SB was equally beneficial as (40), or more crucial (37) than PA. Strong inverse longitudinal relationships between self-reported sedentary time (performed in various forms of sitting) and obesity, independent of PA, have also been found from a prospective cohort study (21). The equivocal findings with the self-report data can be due to a number of factors but an advantage of the present study is that we also examined findings with objective data using the same outcome measures and on the same days.

The objectively estimated TST and MVPA from the SWA were both found to be associated with obesity even after mutually adjusting for each other in addition to other confounders. Moreover, the association of higher TST was stronger than the association of higher MVPA in relation to the odds of being obese. Being physically active may be still beneficial for reducing the odds of being obese but, based on the present results, it is not as beneficial as being less sedentary. Previous research utilizing accelerometry methods reported similar findings with lower levels of TST and more frequent breaks in prolonged sedentary time being favorably associated with BMI, waist circumference and other metabolic risk factors, independent of MVPA time (16-18).

From a behavioral perspective, a person can reduce time spent being sedentary simply by substituting more light-intensity lifestyle activities into their day (i.e. standing, slow walking). Increasing MVPA time, however, may be more challenging since it requires the addition of more purposive, higher intensity activities (e.g. sports, brisk walking or running). In this regard, decreasing TST may be a more effective strategy than increasing MVPA to combat the obesity
epidemic from a public health perspective. However, increases in MVPA time in conjunction with reductions in sedentary time appear to have synergistic effects in reducing the odds of being obese.

This study is one of the few investigations (6, 28, 39) that has directly evaluated discrepancies in the patterns of associations between SB, MVPA and obesity that may be attributable to the method of assessment (subjective versus objective). Overall, the current study found more consistent and stronger associations of SB and MVPA with obesity when using the objective method (i.e. SWA) as opposed to the subjective method (i.e. 24PAR). This observation was similar to the conclusion from a study examining associations of sitting time (as a proxy for SB) and MVPA with BMI in a sample of 317 Chileans (6). In this case, associations with 12 different metabolic risk factors (including BMI) were more consistent and stronger when quantified with an Actigraph (using a cut-off of <100counts) than by the International Physical Activity Questionnaire. For example, significant associations were observed for both objectively estimated SB and MVPA in relation to all the 12 metabolic risk factors (only except for systolic/diastolic blood pressure for MVPA), but subjectively estimated sitting and MVPA time had significant associations with only two risk factors (i.e. insulin and homeostasis model-estimated insulin resistance). Another prior study utilizing National Health and Nutrition Examination Survey data on 5,083 adults found that objectively estimated MVPA was more strongly associated with obesity than TV viewing (assessed by self-report) and TST (assessed by accelerometry with the <100count cut-point) (28). However, the larger ORs reported for the accelerometer-derived MVPA (OR ranges from 2.13-4.00) than the self-report (OR ranges from 1.80-3.67) are similar to the observations reported herein.
Discrepant findings were reported in a study by Stamatakis et al. in 5,948 UK adults (39). Specifically, subjectively assessed SB was significantly associated with BMI (beta coefficient of 0.035) as well as several other cardiovascular risk indicators (ranges of beta coefficients: 0.004-0.083) (only except for high-density lipoprotein cholesterol and glycated haemoglobin), even after adjusting for subjectively assessed MVPA (39). In contrast to the present findings, analyses by accelerometry (with a SB cut-off of <200count) revealed no significant associations of SB with BMI as well as other cardiovascular risk factors (except for total cholesterol with a beta coefficient of 0.010) after adjusting for accelerometry-derived MVPA (39). However, it is noteworthy that this study (39) utilized a self-report to assess the past 28-days’ activities while the accelerometer was used to record data over 7 days. Collectively, the previous studies used vastly different methodologies (i.e. types of self-report tools, sedentary activities, accelerometry sedentary cut-offs, populations). This makes it particularly challenging to make direct comparisons with one another, and to understand why the mixed results were observed among the studies. However, an advantage of the present study is the use of pattern-recognition monitors and the 24PAR, both of which are known to be more accurate than traditional Actigraph accelerometers (25, 47) and long-term recalls (31), respectively. More specifically, the previous studies used the count-based Actigraph cut-point method (i.e. <100 or <200 counts/min) to quantify TST, but previous research found both the 100 and 200 counts/min cut-points to provide underestimation of sitting time relative to direct observation (26). Little is known about the relative accuracy of the Actigraph and SWA for assessing SB, but the ability of the SWA to differentiate various types of activities may provide considerable advantages over the cut-point method for Actigraph in SB research. Further investigations are clearly needed to
better understand the implications of utilizing different measurement tools in identifying associations of SB and MVPA with obesity.

While objective methods can produce relatively accurate estimates of TST, they lack the ability to classify various types of sedentary activities performed in different domains. However, the inclusion of sedentary question items in typical self-report tools has made it possible to examine the associations between an expansive series of sedentary activities (as proxies for SB) and obesity (8, 19, 41). In the current study, no significant associations were observed for any of the 5 sedentary activities (while the association for MVPA was of borderline significance), but this is somewhat inconsistent with previous research. For example, previous research found significant associations between all 6 individual sedentary activities and BMI (8), while two other studies found that not all selected individual sedentary activities had significant associations with BMI (19, 41). The mixed results across the different studies may be attributable to the very large differences in the sample size, the use of measured (19, 41) versus self-reported (8) height and weight to calculate BMI, and/or the use of various cut-points for categorizations of SB. Additional research is needed to establish conclusive evidence on the unique biological contributions of individual SBs to obesity.

Evidence indicates that typical self-report tools requiring longer recall time spans (i.e. past 7-days, 1-month, etc.) are more prone to measurement errors than short-term recall methods (i.e. past 1-day) (31, 36). This has led to conclusions that self-report tools to assess SB have relatively low accuracy (2, 15). Our previous research with this same dataset demonstrated that the 24PAR provided accurate estimates of total energy expenditure relative to the SWA (46). However, we noted in the same study that there was considerable over-estimation of MVPA with
the 24PAR, in particular for heavier and/or older individuals. Similarly, another previous research by our research team (i.e. data not published yet) demonstrated relatively large measurement errors of the 24PAR for assessing various definitions of SB (i.e. non-sleep sedentary time, non-sleep non-lying sedentary time), and identified larger under-estimation of TST by the 24PAR for more obese (and/or older) individuals. Given that measurement errors associated with self-report methods are likely to lessen true associations of SB (and PA) with health outcomes (31), the null associations of TST and weaker associations of MVPA by the 24PAR may be mostly attributable to the complicated patterns of measurement errors inherent in the 24PAR.

Attention has been recently paid to establishing measurement error models to correct for recall biases for estimating energy expenditure from the 24PAR (32), but no such attempts have been made to improve its accuracy for estimating activity time (i.e. SB, MVPA). Through the use of measurement error-correcting models, it is possible for the 24PAR to produce as accurate estimates of SB and MVPA as the SWA. This is particularly important to note from a public health research standpoint since this type of work can enable public health and/or epidemiology researchers to less heavily rely on objective tools, known to be relatively more expensive and harder to administer than subjective methods. The development of measurement error models (and associated calibration equations) would make it possible to obtain more precise estimates of SB and MVPA from the 24PAR. National surveillance tools such as NHANES rely on a parallel 24hour diet assessment so this work would facilitate the development of joint models to more effectively model error in energy balance estimates.
Strengths of the study include the large, representative nature of the sample, the use of strong, temporally matched measures of SB and MVPA and the robust analyses controlling for potential confounding variables. However, there are some limitations of this study that should be considered when interpreting the results. First of all, given that this study capitalized on cross-sectional data, no causal inferences about the SB-obesity relationships can be drawn. The directions of causal relationships between, SB, MVPA and obesity appear still controversial (9, 14). Prospective cohort studies incorporating repetitive objective measures are needed to determine the true causal relationships of SB and MVPA with obesity (35). Another limitation is the assessment of SB and MVPA for a single day, which may not capture the routine activity levels of the participants. The data were collected over a 2-year time span to adjust the potential weather/seasonal variation in activity patterns among the participants but there could be still day-to-day variability for each participant that incorrectly characterize individual profiles. These errors would tend to be random across the sample so results would likely be stronger if more days were assessed. The majority of the participants was Caucasians (89%), which may limit the generalizability of the findings from the present study. We employed a multi-stage sampling strategy to recruit a representative sample of adults in Iowa but this distribution does not reflect the population of the U.S. overall. A final limitation is that results are only capturing the impact of SB and MVPA on obesity. The lack of information about dietary intake limits our ability to fully understand energy balance and weight control.

5.6 Conclusion

Overall, objectively assessed SB and MVPA were both shown to have strong independent associations with obesity. However, reducing time spent sedentary appeared more
important than increasing time spent physically active in reducing the odds of obesity. When the 24PAR was used, SB had no significant associations with obesity and the effects of increasing MVPA were not clear. This may be attributable to the substantial measurement errors inherent in the 24PAR. Developing measurement error models to correct for biases in the 24PAR is required to identify clear associations of SB and MVPA with obesity.

5.7 Acknowledgment

We thank all the participants for the participation in the study. This study was supported by the National Institute of Health grant (R01 HL91024-01A1).

5.8 References


Table 1. Characteristics of the participants by weight status: Non-obesity (n=720) and obesity (n=587).

<table>
<thead>
<tr>
<th></th>
<th>Non-obesity, n (%)</th>
<th>Obesity, n (%)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>410 (56.9)</td>
<td>339 (57.8)</td>
<td>0.769</td>
</tr>
<tr>
<td>Male</td>
<td>310 (43.1)</td>
<td>248 (42.3)</td>
<td></td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>647 (89.9)</td>
<td>519 (88.4)</td>
<td>0.328</td>
</tr>
<tr>
<td>Black</td>
<td>49 (6.8)</td>
<td>52 (8.9)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>24 (3.3)</td>
<td>16 (2.7)</td>
<td></td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than $25,000/yr</td>
<td>121 (16.8)</td>
<td>116 (19.8)</td>
<td>0.048*</td>
</tr>
<tr>
<td>From $25,000 up to $75,000/yr</td>
<td>338 (46.9)</td>
<td>295 (50.3)</td>
<td></td>
</tr>
<tr>
<td>More than $75,000/yr</td>
<td>261 (36.3)</td>
<td>176 (30.0)</td>
<td></td>
</tr>
<tr>
<td><strong>Employment</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full time</td>
<td>416 (57.8)</td>
<td>360 (61.3)</td>
<td>0.143</td>
</tr>
<tr>
<td>Part time</td>
<td>107 (14.9)</td>
<td>66 (11.2)</td>
<td></td>
</tr>
<tr>
<td>Unemployed/retired/full time homemaker</td>
<td>197 (27.4)</td>
<td>161 (27.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Education</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than high school</td>
<td>29 (4.0)</td>
<td>28 (4.8)</td>
<td>0.002*</td>
</tr>
<tr>
<td>High school diploma/some college</td>
<td>381 (52.9)</td>
<td>363 (61.8)</td>
<td></td>
</tr>
<tr>
<td>College/graduate school</td>
<td>310 (43.1)</td>
<td>196 (33.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Marital status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Married/living as married</td>
<td>474 (65.8)</td>
<td>376 (64.1)</td>
<td>0.700</td>
</tr>
<tr>
<td>Divorced/separated/widowed</td>
<td>127 (17.6)</td>
<td>114 (19.4)</td>
<td></td>
</tr>
<tr>
<td>Single/never married</td>
<td>119 (16.5)</td>
<td>97 (16.5)</td>
<td></td>
</tr>
<tr>
<td><strong>Current Smoking status</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>162 (22.5)</td>
<td>92 (15.7)</td>
<td>0.002*</td>
</tr>
<tr>
<td>No</td>
<td>558 (77.5)</td>
<td>495 (84.3)</td>
<td></td>
</tr>
<tr>
<td><strong>Measurement Day of week</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weekend</td>
<td>540 (75.0)</td>
<td>442 (75.3)</td>
<td>0.901</td>
</tr>
<tr>
<td>Weekday</td>
<td>180 (25.0)</td>
<td>145 (24.7)</td>
<td></td>
</tr>
</tbody>
</table>

* indicates significant relationships based on the Chi-square tests (an alpha level = 5%)
Table 2. Average means of various types of sedentary activities as assessed by the 24-hour Physical Activity Recall and SenseWear Armband for non-obese (n=720) and obese (n=587) individuals.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Non-obesity Mean (SD)</th>
<th>Obesity Mean (SD)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>24PAR, min/d</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TST</td>
<td>440.0 (197.3)</td>
<td>460.1 (205.4)</td>
<td>0.0721</td>
</tr>
<tr>
<td>Sitting</td>
<td>410.6 (199.0)</td>
<td>429.4 (205.4)</td>
<td>0.0953</td>
</tr>
<tr>
<td>Screen Time</td>
<td>278.9 (183.0)</td>
<td>286.4 (182.9)</td>
<td>0.4722</td>
</tr>
<tr>
<td>TV viewing</td>
<td>181.9 (140.4)</td>
<td>189.6 (143.3)</td>
<td>0.3680</td>
</tr>
<tr>
<td>Computer use</td>
<td>191.1 (167.4)</td>
<td>191.7 (167.1)</td>
<td>0.9619</td>
</tr>
<tr>
<td>Cell-phone use</td>
<td>92.1 (86.8)</td>
<td>90.0 (93.0)</td>
<td>0.7630</td>
</tr>
<tr>
<td>MVPA</td>
<td>156.6 (171.3)</td>
<td>134.1 (162.2)</td>
<td>0.0156*</td>
</tr>
<tr>
<td><strong>SWA, min/d</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TST</td>
<td>598.3 (198.4)</td>
<td>772.4 (180.2)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>MVPA</td>
<td>119.3 (125.6)</td>
<td>63.2 (89.4)</td>
<td>&lt;0.0001*</td>
</tr>
</tbody>
</table>

Abbreviations: 24PAR - 24-hour Physical Activity Recall; SWA - SenseWear Armband; TST - Total Sedentary Time; MVPA - Moderate-to-vigorous physical activity; SD - Standard Deviation
* indicates significant relationships based on the ANOVA tests (an alpha level = 5%)
Table 3. Odds ratio (95% confidence interval) of obesity for tertiles of total sedentary time (TST) and moderate-to-vigorous physical activity (MVPA) assessed by 24-hour Physical Activity Recall (24PAR) and SenseWear Armband (SWA)

<table>
<thead>
<tr>
<th></th>
<th>24PAR TST (min/day)</th>
<th></th>
<th>Model 1 $^\dagger$</th>
<th>Model 2 $^#$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N £</td>
<td></td>
<td>1.00 (Referent)</td>
<td>1.00 (Referent)</td>
</tr>
<tr>
<td>Low</td>
<td>(&lt;345)</td>
<td>441 (188)</td>
<td>1.08 (0.82-1.43)</td>
<td>1.01 (0.76-1.34)</td>
</tr>
<tr>
<td>Medium</td>
<td>(345-540)</td>
<td>443 (199)</td>
<td>1.22 (0.92-1.61)</td>
<td>1.04 (0.77-1.41)</td>
</tr>
<tr>
<td>High</td>
<td>(≥540)</td>
<td>423 (200)</td>
<td>0.172</td>
<td>0.803</td>
</tr>
<tr>
<td>p for linear trend</td>
<td></td>
<td></td>
<td>0.172</td>
<td>0.803</td>
</tr>
<tr>
<td>MVPA (min/day)</td>
<td></td>
<td></td>
<td>1.00 (Referent)</td>
<td>1.00 (Referent)</td>
</tr>
<tr>
<td>Low</td>
<td>(&lt;44)</td>
<td>425 (209)</td>
<td>0.85 (0.65-1.12)</td>
<td>0.85 (0.65-1.12)</td>
</tr>
<tr>
<td>Medium</td>
<td>(44-145)</td>
<td>449 (204)</td>
<td>0.66 (0.49-0.87)</td>
<td>0.67 (0.49-0.91)</td>
</tr>
<tr>
<td>High</td>
<td>(≥145)</td>
<td>433 (174)</td>
<td>0.004</td>
<td>0.010</td>
</tr>
<tr>
<td>p for linear trend</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SWA</td>
<td>TST (min/day)</td>
<td></td>
<td>1.00 (Referent)</td>
<td>1.00 (Referent)</td>
</tr>
<tr>
<td>Low</td>
<td>(&lt;590)</td>
<td>445 (101)</td>
<td>3.05 (2.24-4.16)</td>
<td>2.89 (2.03-4.11)</td>
</tr>
<tr>
<td>Medium</td>
<td>(590-780)</td>
<td>432 (186)</td>
<td>10.11 (7.23-14.14)</td>
<td>7.41 (4.89-11.22)</td>
</tr>
<tr>
<td>High</td>
<td>(≥780)</td>
<td>430 (300)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>p for linear trend</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>MVPA (min/day)</td>
<td></td>
<td></td>
<td>1.00 (Referent)</td>
<td>1.00 (Referent)</td>
</tr>
<tr>
<td>Low</td>
<td>(&lt;25)</td>
<td>425 (282)</td>
<td>0.26 (0.19-0.35)</td>
<td>0.41 (0.30-0.57)</td>
</tr>
<tr>
<td>Medium</td>
<td>(25-91)</td>
<td>435 (168)</td>
<td>0.14 (0.10-0.20)</td>
<td>0.50 (0.33-0.78)</td>
</tr>
<tr>
<td>High</td>
<td>(≥91)</td>
<td>447 (137)</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>p for linear trend</td>
<td></td>
<td></td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

$^\dagger$ indicates the number of participants; numbers in parenthesis indicate the number of obese individuals.

$^\dagger$ Adjusted for gender, age, ethnicity, income, employment, education, marital status, smoking status and measurement day of week

$^\#$ Adjusted for all covariates included in Model 1 plus total sedentary time (for MVPA) or MVPA (for TST)

Abbreviations: 24PAR - 24-hour Physical Activity Recall; SWA - SenseWear Armband; TST - Total Sedentary Time; MVPA - Moderate-to-vigorous physical activity; CI - Confidence Interval
Table 4. Odds ratio (95% confidence interval) of obesity for total sedentary time (TST) and moderate-to-vigorous physical activity (MVPA) in TST and MVPA stratified analyses assessed by 24-hour Physical Activity Recall (24PAR) and SenseWear Armband (SWA)

<table>
<thead>
<tr>
<th></th>
<th>MVPA (min/day)</th>
<th>TST (min/day)</th>
<th>Odds Ratio (95% CI)</th>
<th>TST (min/day)</th>
<th>MVPA (min/day)</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24PAR</td>
<td>Low (&lt;44)</td>
<td>Low (&lt;345)</td>
<td>1.00 (Referent)</td>
<td>Low (&lt;345)</td>
<td>Low (&lt;44)</td>
<td>1.00 (Referent)</td>
</tr>
<tr>
<td></td>
<td>Medium+High (≥44)</td>
<td>Low (&lt;345)</td>
<td>0.96 (0.56-1.64)</td>
<td>Medium+High (≥345)</td>
<td>Low (&lt;44)</td>
<td>0.84 (0.50-1.41)</td>
</tr>
<tr>
<td></td>
<td>Medium+High (≥44)</td>
<td>Medium+High (≥345)</td>
<td>1.00 (Referent)</td>
<td>Medium+High (≥345)</td>
<td>Low (&lt;44)</td>
<td>1.00 (Referent)</td>
</tr>
<tr>
<td>SWA</td>
<td>Low (&lt;25)</td>
<td>Low (&lt;590)</td>
<td>1.00 (Referent)</td>
<td>Low (&lt;590)</td>
<td>Low (&lt;25)</td>
<td>1.00 (Referent)</td>
</tr>
<tr>
<td></td>
<td>Medium+High (≥25)</td>
<td>Medium+High (≥590)</td>
<td>3.29 (1.30-8.35)</td>
<td>Medium+High (≥590)</td>
<td>Low (&lt;25)</td>
<td>0.28 (0.10-0.78)</td>
</tr>
<tr>
<td></td>
<td>Medium+High (≥25)</td>
<td>Low (&lt;590)</td>
<td>1.00 (Referent)</td>
<td>Medium+High (≥590)</td>
<td>Low (&lt;25)</td>
<td>0.32 (0.23-0.44)</td>
</tr>
<tr>
<td></td>
<td>Medium+High (≥25)</td>
<td>Medium+High (≥590)</td>
<td>3.79 (2.75-5.22)</td>
<td>Medium+High (≥590)</td>
<td>Low (&lt;25)</td>
<td>0.32 (0.23-0.44)</td>
</tr>
</tbody>
</table>

Analyses were adjusted for gender, age, ethnicity, income, employment, education, marital status, smoking status and measurement day of week.
The medium and high groups of TST and MVPA (i.e. Medium+High) were combined for both 24PAR and SWA based on consistent and similar results in medium and high groups of TST and MVPA in independent analyses (Table 3).

Abbreviations: 24PAR - 24-hour Physical Activity Recall; SWA - SenseWear Armband; TST - Total Sedentary Time; MVPA - Moderate-to-vigorous physical activity; CI - Confidence Interval
Figure 1. Joint associations of total sedentary time (TST) and moderate-to-vigorous physical activity (MVPA) assessed by 24-hour Physical Activity Recall (24PAR; panel A) and SenseWear Armband (SWA; panel B) in relation to obesity. Analyses were adjusted for gender, age, ethnicity, income, employment, education, marital status, smoking status and measurement day of week. The medium and high groups of TST and MVPA (i.e. Medium+High) were combined for both 24PAR and SWA based on consistent and similar results in medium and high groups of TST and MVPA in independent analyses (Table 3). With the 24PAR, the number of individuals (number of obesity) in the low, and medium + high TST groups was 362 (152), and 520 (226) in the medium + high MVPA group; 79 (36), and 346 (173) in the low MVPA group, respectively. With the SWA, the number of individuals (number of obesity) in the low, and medium + high TST groups was 422 (93), and 460 (212) in the medium + high MVPA group; 23 (8), and 402 (274) in the low MVPA group, respectively.
CHAPTER 6. CONCLUSION

SB has been recently indicated as an independent, modifiable risk factor for obesity as well as other detrimental health outcomes. Research on the epidemiology of SB is a rapidly growing area of scientific interest, and considerable efforts have been placed on clearly understanding the relationships between SB and health from a public health perspective. However, due to the relatively short history of research on SB, there are a number of gaps that must be filled to advance this research. This dissertation was designed to help fill some of these gaps by directly referencing the first three phases (i.e. Phases i, ii and iii) of the behavioral epidemiology framework (See Figure 1) (1). Specifically, the study was the first to examine the validity of SB estimates for multiple demographic indicators (i.e. age, gender, BMI) (Phase ii). The study also provides perhaps the most detailed evaluation of the context of SB at the population level (Phase iii). A final research gap was the evaluation of independent and joint effects of SB and MVPA (using both measures) (Phase i). Summaries of the three dissertation studies are provided below to bring the results together.

Results from the first study (Chapter 3) indicated that the 24PAR and SWA provided equivalent estimates only for TST (not for NSST and NSNLST). A notable observation was the systematic pattern of measurement errors with extremely or minimally sedentary individuals being able to more accurately recall their previous day’s sedentary activities than moderately sedentary individuals. Specific patterns and distributions of measurement errors of the 24PAR were also identified. For example, relatively older and/or heavier individuals tended to underestimate sedentary time in comparison with younger and/or normal weight individuals. These findings support the need to develop independent measurement error models to correct for
recall biases associated with the 24PAR in order to obtain unbiased daily estimates of sedentary time. The 24PAR, as a subjective method, has good utility and has been shown to be more accurate than traditional recall methods requiring relatively longer recall time spans. However, developing measurement error models can substantially improve the accuracy of the 24PAR for estimating SB. Our research team (in partnership with researchers in statistics) has been working to develop measurement error models for EE and MVPA using the PAMS data and parallel work is planned to develop these models for SB. It is hopeful that measurement errors inherent in assessment of SB with the 24PAR can be corrected through the measurement error modeling, which would then enable the 24PAR to provide as accurate estimates of sedentary time as the SWA does.

The second study (Chapter 4) relied on the unique feature of the 24PAR that provides detailed information about types, location and purpose of sedentary activities. A variety of reported sedentary activities incorporated a form of ‘sitting’ but the novel aspect of the study is the exploration of the context of these behaviors. The time allocations of purpose and location codes varied by socio-demographic indicators, suggesting that individuals with different socio-demographic characteristics have different patterns of where (i.e. location) and why (i.e. purpose) they spent time sedentary. For example, individuals with higher levels of academic background reported to be more sedentary ‘at Work’ and ‘for Work’ in comparison with those with lower education levels. Similarly, individuals with higher levels of income exhibited a greater amount of time spent sedentary in comparison with those with lower income levels. SB research thus far has primarily focused on convenience samples but an advantage of the present study was the representative nature of the sample. The findings from this particular study suggest that there is considerable variability in the nature and context of sedentary behavior across
different adult populations. This study may provide insights for informing and developing future intervention and policy studies to minimize time spent sedentary in adults. Another implication of this study was that the 24PAR tool proved to be useful for identifying specific patterns of context of SB.

The third study (Chapter 5) demonstrated that associations between SB and health outcomes varied when SB was assessed with the 24PAR and the SWA. Independent and joint associations of SB and MVPA on obesity were observed when the SWA was used. Individuals that spent relatively more time being sedentary had substantially higher odds of being obese compared with those that spent less time being sedentary, regardless of the levels of MPVA (as well as other potential confounders). Similarly, individuals with lower levels of MPVA exhibited higher odds of being obesity compared with those with higher levels of MVPA, independent of the time spent sedentary. However, the beneficial effects from lower sedentary time were greater than the effects from more MVPA. This evidence suggests that reducing time spent sedentary may be a more effective strategy than increasing time being physically active in the prevention of obesity. In general, it is much easier for average adults to reduce sedentary time than increasing time spent on purposive high intensity activities in daily lives. To be specific, prolonged SB can be easily broken by a number of lifestyle activities (i.e., standing, walking, etc.). However, when it comes to performing MVPA, a wide variety of physiological (i.e. fitness), psychological (i.e. self-efficacy) and/or environmental (i.e. weather) factors are typically considered, which makes it harder to do.

Another important implication to note from this study is that as assessed by the 24PAR, significant associations were observed only for MVPA (no significant associations for SB) and the magnitudes of the associations for MVPA with the 24PAR were smaller than those with the
SWA. This appears to be attributable to the considerable measurement errors in the estimation of SB (as observed in Chapter 3). However, most epidemiological studies (in particular, prospective cohort studies) have utilized self-report tools, mainly due to the low cost and ease of use. The use of large sample sizes may compensate for the large measurement errors from self-report tools, thereby increasing the likelihood of detecting significant associations. However, determining clearer (causal) relationships may be possible in the future with broader use of objective measurement tools and/or measurement error models for self-report tools.

Collectively, this dissertation contributes to improving the understanding of the complex nature of sedentary lifestyles and its relation to obesity from an epidemiological perspective. As an innovative self-report tool, the 24PAR has shown promise for accurately assessing SB as well as capturing the specific context (i.e. purpose and location) of SB at the population level. This may help to dramatically advance SB research since contemporary SB research has been limited by the use of long-term recall methods (i.e. more susceptible to errors than 24PAR) and their lack of abilities to provide detailed information on the context of SB. Nevertheless, the measurement errors associated with the 24PAR appear to lessen the relationships between SB and obesity. Therefore, it is important to develop measurement error models to correct the errors of the 24PAR, and to apply them for epidemiological research so that associations of SB with various health outcomes can be more effectively examined. While the dissertation addressed several critical research questions, there still remains a series of research topics that need to be studied to further advance research on the sedentary lifestyles in relation to obesity in adult populations. The following bullet points provide recommendations and future directions for conducting SB research (not ordered by importance):
• Use the 24PAR for assessing total sedentary time, but be cautious of potential large errors for assessing other definitions of SB.

• Be informed of potential measurement errors when using the 24PAR for identifying specific patterns and associations of SB in relation to health outcomes (including obesity).

• Improve the accuracy of the 24PAR and SWA for differentiating sleep and lying down time.

• Develop measurement error models to correct for errors associated with the 24PAR as well as other self-report tools.

• Utilize both subjective and objective measurement tools to obtain more accurate estimates of sedentary time, along with detailed context information of SB.

APPENDIX A. TELEPHONE SCREENING & RESPONDENT SELECTION

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Case ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case ID</td>
<td>CaseID</td>
</tr>
<tr>
<td>First digit = Quarter</td>
<td></td>
</tr>
<tr>
<td>Second digit = County</td>
<td></td>
</tr>
<tr>
<td>1 = Black Hawk</td>
<td></td>
</tr>
<tr>
<td>2 = Dallas</td>
<td></td>
</tr>
<tr>
<td>3 = Marshall</td>
<td></td>
</tr>
<tr>
<td>4 = Polk</td>
<td></td>
</tr>
<tr>
<td>Third-Fifth digits = Numeric identifier</td>
<td></td>
</tr>
</tbody>
</table>

S1b. What county do you live in? 

Polk
Black Hawk
Dallas
Marshall

IF ANOTHER COUNTY, RECORD CASE AS NOT ELIGIBLE

S2. How many adults between 21 and 70 years of age currently live there?

SELECTED PERSON INFORMATION.

<table>
<thead>
<tr>
<th>Selected Person Gender</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 = Male</td>
<td></td>
</tr>
<tr>
<td>2 = Female</td>
<td></td>
</tr>
</tbody>
</table>

Selected Person Age | Age |

Selected Person Hispanic | Hispanic |
| 1 = Yes                |        |
| 2 = No                 |        |

Variable Name
Selected Person Black

THE CODE FOR BLACK/NON-BLACK IS OBTAINED FROM QUESTION S9.

1 = Yes, Black
2 = No, Not Black

S18. Do you smoke cigarettes, cigars, or a pipe? S18

1 = Yes
2 = No

S19. What is the highest level of education you have completed? S19

1 = Less than high school
2 = High school diploma (includes GED)
3 = Some college/post-high school (includes AA, vocational degree)
4 = College graduate (Bachelors, 4-year degree)
5 = Graduate degree (Masters, PhD, MD, JD, etc)

S20. Are you currently… S20

1 = employed full time
2 = employed part time
3 = unemployed
4 = retired,
5 = full time homemaker
6 = something else  [RECODE])
7 = Disabled
8 = Student
S21. What is your current (or primary) job? (PROBE: What do you do in a typical day?)  Coded using 2000 SOC codes.

- 11 = Management Occupations
- 13 = Business and Financial Operations Occupations
- 15 = Computer and Mathematical Occupations
- 17 = Architecture and Engineering Occupations
- 19 = Life, Physical, and Social Science Occupations
- 21 = Community and Social Services Occupations
- 23 = Legal Occupations
- 25 = Education, Training, and Library Occupations
- 27 = Arts, Design, Entertainment, Sports, and Media Occupations
- 29 = Healthcare Practitioners and Technical Occupations
- 31 = Healthcare Support Occupations
- 33 = Protective Service Occupations
- 35 = Food Preparation and Serving Related Occupations
- 37 = Building and Grounds Cleaning and Maintenance Occupations
- 39 = Personal Care and Service Occupations
- 41 = Sales and Related Occupations
- 43 = Office and Administrative Support Occupations
- 45 = Farming, Fishing, and Forestry Occupations
- 47 = Construction and Extraction Occupations
- 49 = Installation, Maintenance, and Repair Occupations
- 51 = Production Occupations
- 53 = Transportation and Material Moving Occupations
- 55 = Military Specific Occupations
- 98 = Refused
- 99 = Missing

S22. What was your total household income last year, in [FILL YEAR]?  

- 1 = Less than $25,000
- 2 = From $25,000 up to $50,000
- 3 = From $50,000 up to $75,000
- 4 = From $75,000 up to $100,000
- 5 = More than $100,000
- 8 = Refused
- 9 = Don’t Know
S23. What is your current marital status? Are you…
   1 = married or living as married,
   2 = divorced or separated,
   3 = widowed, or
   4 = single, never married?

S24. How many people currently live in your household?

S25. IF S24>1, ASK: How many of those people are less than 18 years old?
   IF S24 = 1, CODE 0.

   1 = on a farm or in a rural area,
   2 = in a town of less than 2500,
   3 = in a town of 2500 up to 10,000,
   4 = in a town of 10,000 up to 50,000,
   5 = in a city of 50,000 up to 100,000
   6 = or in a city or metropolitan area of 100,000 or more?

HOUSEHOLD ROSTER SCREENING.

Person 1 Information.

S6. Is [NAME] male or female?
   1 = Male
   2 = Female

S7. How old (are you / is [NAME]) as of today?
   98 = Refused
   99 = Don’t Know

S8. (Are you / Is [NAME]) Hispanic?
   1 = Yes
   2 = No
   9 = Don’t Know
S9. What is (your / NAME’s) race? (Are you / Is s/he) white, black or African American, Asian or Pacific Islander, Native American, or something else? (You may choose more than one answer.)

1 = White
2 = Black or African American
3 = Asian or Pacific Islander
4 = American Indian
5 = Something else (Please specify:)
8 = REFUSED
9 = MISSING/DON’T KNOW

Race listed first S9_1_1
Race listed second S9_1_2
Race listed third S9_1_3
Race listed fourth S9_1_4
Race listed fifth S9_1_5
Specify other race S9_1.otr

S10. IF FEMALE AND < 50 YEARS OLD, ASK: S10_1
(Are you / Is [NAME]) currently pregnant or (nursing/breast-feeding)?

1 = Yes
2 = No

S11. (Do you / Does [NAME]) currently have a health condition S11_1
that prevents (you/him/her) from walking?

1 = Yes
2 = No

S12. (Do you / Does [NAME]) currently use portable oxygen, a S12_1
pacemaker, or other electronic medical device?

1 = Yes
2 = No
S13. Would (you / [NAME]) be mentally and physically able to complete an interview over the telephone and answer written questions?
   1 = Yes
   2 = No

Person 1 Eligible? (IF S10, 11 & 12 = NO & S13 = YES, PERSON IS ELIGIBLE) Per_1_Eli
   1 = Yes
   2 = No

Person 2 Information.

S6. Is [NAME] male or female? S6_2
   1 = Male
   2 = Female
   8 = Refused

S7. How old (are you / is [NAME]) as of today? S7_2
   98 = Refused
   99 = Don’t Know

S8. (Are you / Is [NAME]) Hispanic? S8_2
   1 = Yes
   2 = No
   8 = Refused
Variable Name

S9. What is (your / NAME’s) race? (Are you / Is s/he) white, black or African American, Asian or Pacific Islander, Native American, or something else? (You may choose more than one answer.)

1 = White
2 = Black or African American
3 = Asian or Pacific Islander
4 = American Indian
5 = Something else (Please specify)
8 = Refused

Race listed first S9_2_1
Race listed second S9_2_2
Race listed third S9_2_3
Race listed fourth S9_2_4
Race listed fifth S9_2_5
Specify other race S9_2_otr

S10. IF FEMALE AND < 50 YEARS OLD, ASK: S10_2
(Are you / Is [NAME]) currently pregnant or (nursing/breast-feeding)?

1 = Yes
2 = No

S11. (Do you / Does [NAME]) currently have a health condition S11_2
that prevents (you/him/her) from walking?

1 = Yes
2 = No
8 = Refused

S12. (Do you / Does [NAME]) currently use portable oxygen, a S12_2
pacemaker, or other electronic medical device?

1 = Yes
2 = No
8 = Refused
S13. Would (you / [NAME]) be mentally and physically able to complete an interview over the telephone and answer written questions?
   1 = Yes
   2 = No
   8 = Refused

Person 2 Eligible? (IF S10, 11 & 12 = NO & S13 = YES, PERSON IS ELIGIBLE)
   1 = Yes
   2 = No

Person 3 Information.

S6. Is [NAME] male or female?
   1 = Male
   2 = Female
   8 = Refused

S7. How old (are you / is [NAME]) as of today?
   98 = Refused

S8. (Are you / Is [NAME]) Hispanic?
   1 = Yes
   2 = No
S9. What is (your / NAME’s) race? (Are you / Is s/he) white, black or African American, Asian or Pacific Islander, Native American, or something else? (You may choose more than one answer.)

1 = White
2 = Black or African American
3 = Asian or Pacific Islander
4 = American Indian
5 = Something else (Please specify)
8 = Refused

Race listed first
Race listed second
Race listed third
Race listed fourth
Race listed fifth
Specify other race

S10. IF FEMALE AND < 50 YEARS OLD, ASK:
(Are you / Is [NAME]) currently pregnant or (nursing/breast-feeding)?
1 = Yes
2 = No

S11. (Do you / Does [NAME]) currently have a health condition that prevents (you/him/her) from walking?
1 = Yes
2 = No
8 = Refused

S12. (Do you / Does [NAME]) currently use portable oxygen, a pacemaker, or other electronic medical device?
1 = Yes
2 = No
8 = Refused
9 = Don’t Know
S13. Would (you / [NAME]) be mentally and physically able to complete an interview over the telephone and answer written questions?

1 = Yes
2 = No
8 = Refused

Person 3 Eligible? (IF S10, 11 & 12 = NO & S13 = YES, PERSON IS ELIGIBLE)

1 = Yes
2 = No

Person 4 Information.

S6. Is [NAME] male or female?

1 = Male
2 = Female

S7. How old (are you / is [NAME]) as of today?

S8. (Are you / Is [NAME]) Hispanic?

1 = Yes
2 = No
S9. What is (your / NAME’s) race? (Are you / Is s/he) white, black or African American, Asian or Pacific Islander, Native American, or something else? (You may choose more than one answer.)

1 = White
2 = Black or African American
3 = Asian or Pacific Islander
4 = American Indian
5 = Something else (Please specify)

Race listed first S9_4_1
Race listed second S9_4_2
Race listed third S9_4_3
Race listed fourth S9_4_4
Race listed fifth S9_4_5
Specify other race S9_4_otr

S10. IF FEMALE AND < 50 YEARS OLD, ASK: S10_4
(Are you / Is [NAME]) currently pregnant or (nursing/breast-feeding)?
1 = Yes
2 = No

S11. (Do you / Does [NAME]) currently have a health condition S11_4
that prevents (you/him/her) from walking?
1 = Yes
2 = No

S12. (Do you / Does [NAME]) currently use portable oxygen, a S12_4
pacemaker, or other electronic medical device?
1 = Yes
2 = No
S13. Would (you / [NAME]) be mentally and physically able to complete an interview over the telephone and answer written questions?  
1 = Yes  
2 = No

Person 4 Eligible? (IF S10, 11 & 12 = NO & S13 = YES, PERSON IS ELIGIBLE)  
1 = Yes  
2 = No

Person 5 Information.

S6. Is [NAME] male or female?  
1 = Male  
2 = Female

S7. How old (are you / is [NAME]) as of today?  

S8. (Are you / Is [NAME]) Hispanic?  
1 = Yes  
2 = No
Variable Name

S9. What is (your / NAME’s) race? (Are you / Is s/he) white, black or African American, Asian or Pacific Islander, Native American, or something else? (You may choose more than one answer.)

1 = White
2 = Black or African American
3 = Asian or Pacific Islander
4 = American Indian
5 = Something else (Please specify)

Race listed first S9_5_1
Race listed second S9_5_2
Race listed third S9_5_3
Race listed fourth S9_5_4
Race listed fifth S9_5_5
Specify other race S9_5_otr

S10. IF FEMALE AND < 50 YEARS OLD, ASK: S10_5
(Are you / Is [NAME]) currently pregnant or (nursing/breast-feeding)?

1 = Yes
2 = No

S11. (Do you / Does [NAME]) currently have a health condition that prevents (you/him/her) from walking? S11_5

1 = Yes
2 = No

S12. (Do you / Does [NAME]) currently use portable oxygen, a pacemaker, or other electronic medical device? S12_5

1 = Yes
2 = No
S13. Would (you / [NAME]) be mentally and physically able to complete an interview over the telephone and answer written questions?

1 = Yes
2 = No

Person 5 Eligible? (IF S10, 11 & 12 = NO & S13 = YES, PERSON IS ELIGIBLE)

1 = Yes
2 = No

**Person 6 Information.**

S6. Is [NAME] male or female?

1 = Male
2 = Female

S7. How old (are you / is [NAME]) as of today?

S8. (Are you / Is [NAME]) Hispanic?

1 = Yes
2 = No
S9. What is (your / NAME’s) race? (Are you / Is s/he) white, black or African American, Asian or Pacific Islander, Native American, or something else? (You may choose more than one answer.)

1 = White
2 = Black or African American
3 = Asian or Pacific Islander
4 = American Indian
5 = Something else (Please specify)

Race listed first S9_6_1
Race listed second S9_6_2
Race listed third S9_6_3
Race listed fourth S9_6_4
Race listed fifth S9_6_5
Specify other race S9_6_otr

S10. IF FEMALE AND < 50 YEARS OLD, ASK: S10_6
(Are you / Is [NAME]) currently pregnant or (nursing/breast-feeding)?

1 = Yes
2 = No

S11. (Do you / Does [NAME]) currently have a health condition that prevents (you/him/her) from walking? S11_6

1 = Yes
2 = No

S12. (Do you / Does [NAME]) currently use portable oxygen, a pacemaker, or other electronic medical device? S12_6

1 = Yes
2 = No
S13. Would (you / [NAME]) be mentally and physically able to complete an interview over the telephone and answer written questions?
   1 = Yes
   2 = No

Person 6 Eligible? (IF S10, 11 & 12 = NO & S13 = YES, PERSON IS ELIGIBLE)  Per_6_Eli
   1 = Yes
   2 = No

PARTICIPANT SELECTION & FINAL SCREENER STATUS.

Row of adult selected to participate.  Selected
   0 = Eligible HH, screener not complete so no adult selected

Language used for the interview.  Language
   1 = English
   2 = Spanish

Assigned Day of Week for wearing Armband for PAR1 and PAR2.  DOW1, DOW2
   1 = Sunday
   2 = Monday
   3 = Tuesday
   4 = Wednesday
   5 = Thursday
   6 = Friday
   7 = Saturday

Number of Call Attempts  Call_Att

Screener Outcome  Screener_Outcome

Screener Outcome comments  Screener_Comment
S15. Can I get your full name and address so that we can send you a letter with more information about the project?

**SAMPLE INFORMATION.**

- Sample City: Sample City
- Sample Zip Code: Sample Zip
- Sample County: Sample County
- Replicate: Rep
- CoStratum: CoStratum
- FIPS Code: FIPS
- Census Tract: Census Trac
- Quarter: Quarter
- Income Year: Income Year

**COMPLETION STATUS.**

- Screener Interview Date or Date of Final Outcome: Int_Date
- Screener Interviewer ID: Int_ID
- PAR 1 Outcome: PAR1_Outcome
- PAR2 Outcome: PAR2_Outcome
- PAPQ Outcome: PAPQ_Outcome
- Comments regarding PAR & PAPQ completion: PAR_PAPQComment
APPENDIX B. 24-HOUR PHYSICAL ACTIVITY RECALL

Hello, this is [INTERVIEWER NAME] calling for Iowa State University. May I please speak to [RESPONDENT NAME]?

IF NOT AVAILABLE, SCHEDULE CALLBACK DAY/TIME.

I’m calling about the Physical Activity Measurement Study that you are participating in, and I’d like to talk with you about what you did yesterday when you were wearing the armband. This will take about 20 minutes. Is this a good time for you?

IF NO, SCHEDULE CALLBACK DAY/TIME.

Before we begin I want to assure you that all the information you provide will be kept completely confidential. Your participation is voluntary, and you may refuse to answer any question that you feel is too personal.

In this interview, I will ask you to report the activities you did yesterday, [FILL DAY OF WEEK], [FILL DATE]. We will cover everything in that 24 hour period, from midnight to midnight, in 6-hour time periods. I will ask you to tell me what you did and how much time you spent on each activity. This will include only the activities you actually did yesterday, not the things that you usually do.

1. First of all, when did you start wearing the armband – what day and time?

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>Date</th>
<th>Time</th>
<th>AM/PM</th>
</tr>
</thead>
</table>

2. And when did you take the armband off for good?

<table>
<thead>
<tr>
<th>Day of Week</th>
<th>Date</th>
<th>Time</th>
<th>AM/PM</th>
</tr>
</thead>
</table>
NIGHT (Midnight to 6 am).

Now think about the time between midnight and 6:00 AM on [DAY OF WEEK]. (Think about where you went, what you did, and who you were with. We can record types of activities, such as getting washed and dressed as one activity, and we don’t need to include things that took less than 5 minutes.)

PROBE FOR EACH ACTIVITY, BEGINNING AT MIDNIGHT. RECORD LOCATION, PURPOSE & ACTIVITY CODES AS WELL AS HOURS/MINUTES. PROBE AS NEEDED. SEE p. 7 FOR CODES AND PROBES.

<table>
<thead>
<tr>
<th>Location</th>
<th>Purpose</th>
<th>Activity</th>
<th>How long?</th>
<th>Running Total (minutes)</th>
<th>Time Remaining (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CHECK THE RUNNING TOTAL TO SEE IF YOU NEED TO ACCOUNT FOR MORE TIME OR IF YOU HAVE TOO MUCH TIME RECORDED.

FINAL PROBE: Can you think of any other activities that you participated in yesterday between midnight and 6:00 AM that we haven’t included yet?
MORNING (6 am to Noon).

Next I will ask about your activities yesterday from 6:00 am until noon. Think about where you went, what you did, and who you were with. (We can record types of activities, such as getting washed and dressed as one activity, and we don’t need to include things that took less than 5 minutes.)

FOR EACH ACTIVITY, RECORD LOCATION, PURPOSE & ACTIVITY CODES AS WELL AS HOURS/MINUTES. PROBE AS NEEDED. SEE p. 7 FOR CODES AND PROBES.

<table>
<thead>
<tr>
<th>Location</th>
<th>Purpose</th>
<th>Activity</th>
<th>How long?</th>
<th>Running Total</th>
<th>Time Remaining</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hours</td>
<td>Minutes</td>
<td>minutes</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CHECK THE RUNNING TOTAL TO SEE IF YOU NEED TO ACCOUNT FOR MORE TIME OR IF YOU HAVE TOO MUCH TIME RECORDED.

FINAL PROBE: Can you think of any other activities that you participated in yesterday from 6:00 am until noon that we haven’t included yet?
**AFTERNOON.**
Next I will ask about your activities from Noon yesterday until 6:00 pm. Remember, we want to record the activities you actually did yesterday, not the things you usually do. Think about where you went, what you did, and who you were with.

**FOR EACH ACTIVITY, RECORD LOCATION, PURPOSE & ACTIVITY CODES AS WELL AS HOURS/MINUTES. PROBE AS NEEDED. SEE p. 7 FOR CODES AND PROBES.**

<table>
<thead>
<tr>
<th>Location</th>
<th>Purpose</th>
<th>Activity</th>
<th>How long?</th>
<th>Running Total (minutes)</th>
<th>Time Remaining (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CHECK THE RUNNING TOTAL TO SEE IF YOU NEED TO ACCOUNT FOR MORE TIME OR IF YOU HAVE TOO MUCH TIME RECORDED.

**FINAL PROBE:** Can you think of any other activities that you participated in from Noon yesterday until 6:00 pm that we haven’t included yet?
**EVENING.**
Next I will ask about your activities from 6 pm yesterday until Midnight. Remember, we want to record the activities you actually did yesterday, not the things you usually do. Think about where you went, what you did, and who you were with.

FOR EACH ACTIVITY, RECORD LOCATION, PURPOSE & ACTIVITY CODES AS WELL AS HOURS/MINUTES. PROBE AS NEEDED. SEE p. 7 FOR CODES AND PROBES.

<table>
<thead>
<tr>
<th>Location</th>
<th>Purpose</th>
<th>Activity</th>
<th>How long?</th>
<th>Running Total (minutes)</th>
<th>Time Remaining (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Hours</td>
<td>Minutes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CHECK THE RUNNING TOTAL TO SEE IF YOU NEED TO ACCOUNT FOR MORE TIME OR IF YOU HAVE TOO MUCH TIME RECORDED.

FINAL PROBE: Can you think of any other activities that you participated in from 6 pm yesterday until Midnight that we haven’t included yet?
WRAP UP.

I think we have all of the time yesterday accounted for. I have just a couple of other questions.

How many flights of stairs did you climb yesterday? ___________

Can you think of any other activities that you participated in yesterday that we haven’t included yet?

BACK UP AND MAKE ANY NECESSARY CORRECTIONS.

That’s all the information we need today. One of our research staff will be stopping by to pick up the armband and monitor, and s/he will give you a check for $50 to thank you for your time. (You probably already have that day and time scheduled.)

IF FIRST 24-HR PAR, SAY:
S/He will also schedule the next date for you to wear the armband, which will be sometime in the next 2 or 3 weeks. You will receive another $50 for wearing the armband for a day and doing another interview just like this one.

IF SECOND 24-HR PAR, SAY:
The last part of this study is a paper survey that we will send you in the mail in a couple of weeks, along with a $25 check to thank you for your time and effort. When the survey arrives, please complete it as soon as possible and return it to us in the postage-paid return envelope that is enclosed.

CLOSE.
Thank you very much for your help. Iowa State University greatly appreciates your cooperation and assistance with this important study.
LOCATION/CONTEXT CODES:

1 = Work/Volunteer
2 = Home – Indoor (your own home)
3 = Home – Outdoor (your own home)
4 = Transportation
5 = Community (Not Home, Not Work, Not Transportation – Everything else)
6 = (Unlabeled)
7 = (Unlabeled)

PURPOSE/FUNCTION CODES:

1 = Work (paid job)
2 = Home & Family Care (family can include extended family)
3 = Volunteering
4 = Exercise/Sports (for fitness or for fun)
5 = Education (formal education, for work or a degree)
6 = Leisure (Discretionary time, not any of the above categories – Everything else)
7 = (Unlabeled)
8 = (Unlabeled)

ACTIVITY/BEHAVIOR COMPENDIUM CODES.

(See Compendium file for codes.)

PROBING FOR INFORMATION.

Proceed in a roughly chronological manner.
• What did you do next?
• What did you do after you ___________?

Larger blocks of time at work or at other types of activities may need to be probed differently:
• What did you do most of the time?
• What percent of the time were you doing that?
• What percent of the time were you sitting/standing/walking/carrying things?
• During this time, how many minutes would you say you were ____________?
• Record activities that are done for at least 5 minutes. Isolated activities lasting less than 5 minutes do not need to be included. However, activities of short duration (< 5 minutes) that are repeated within a 6-hour reporting period can be recorded if they total 5 minutes or more.
### APPENDIX C. ACTIVITY COMPRENDIUM FOR 24PAR INTERVIEWS

<table>
<thead>
<tr>
<th>Code</th>
<th>Mets</th>
<th>PAMS PAR Activity Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1010</td>
<td>4</td>
<td>bicycling</td>
</tr>
<tr>
<td>1015</td>
<td>8</td>
<td>bicycling, fast (road, BMX, mountain bikes)</td>
</tr>
<tr>
<td>2010</td>
<td>7</td>
<td>stationary bicycle</td>
</tr>
<tr>
<td>2018</td>
<td>10.5</td>
<td>spin class, stationary bicycle</td>
</tr>
<tr>
<td>2020</td>
<td>8</td>
<td>exercises general (pushups/situps/pullups/jumping jacks) vigorous</td>
</tr>
<tr>
<td>2040</td>
<td>8</td>
<td>circuit training, aerobic movement with minimal rest</td>
</tr>
<tr>
<td>2050</td>
<td>6</td>
<td>weight lifting, body building, vigorous</td>
</tr>
<tr>
<td>2060</td>
<td>5.5</td>
<td>health club exercise, general</td>
</tr>
<tr>
<td>2070</td>
<td>7</td>
<td>rowing machine</td>
</tr>
<tr>
<td>2071</td>
<td>7</td>
<td>elliptical trainer machine</td>
</tr>
<tr>
<td>2080*</td>
<td>7</td>
<td>ski machine</td>
</tr>
<tr>
<td>2100</td>
<td>2.5</td>
<td>yoga</td>
</tr>
<tr>
<td>2101</td>
<td>2.5</td>
<td>stretching and flexibility exercises</td>
</tr>
<tr>
<td>2130</td>
<td>3</td>
<td>weight lifting, light/moderate</td>
</tr>
<tr>
<td>3015</td>
<td>6.5</td>
<td>aerobics, general (includes step aerobics, jazzercise, slimnastics, etc.)</td>
</tr>
<tr>
<td>3025</td>
<td>4.5</td>
<td>dancing, all kinds</td>
</tr>
<tr>
<td>4030</td>
<td>2.5</td>
<td>fishing, sitting in boat or on shore/dock</td>
</tr>
<tr>
<td>4040</td>
<td>3.5</td>
<td>fishing, standing on shore, dock, etc.</td>
</tr>
<tr>
<td>4070*</td>
<td>2.5</td>
<td>hunting, sitting in blind or hide</td>
</tr>
<tr>
<td>4100</td>
<td>5</td>
<td>hunting, standing/walking</td>
</tr>
<tr>
<td>4130</td>
<td>2.5</td>
<td>target shooting (skeet or trap)</td>
</tr>
<tr>
<td>5011</td>
<td>2.5</td>
<td>cleaning, light (dust, straighten up, empty trash)</td>
</tr>
<tr>
<td>5012</td>
<td>3.5</td>
<td>cleaning, moderate (vacuum, mop, sweep)</td>
</tr>
<tr>
<td>5013</td>
<td>4</td>
<td>cleaning, vigorous (scrub floors, walls, &amp; bathroom, sweep outside, clean garage)</td>
</tr>
<tr>
<td>5020</td>
<td>3</td>
<td>washing cars, boats, heavy equipment</td>
</tr>
<tr>
<td>5022</td>
<td>3</td>
<td>clean exterior of house (wash windows, deck, garage) or outbuildings</td>
</tr>
<tr>
<td>5025</td>
<td>2.5</td>
<td>HH tasks all at once, light</td>
</tr>
<tr>
<td>5026</td>
<td>3.5</td>
<td>HH tasks all at once, moderate</td>
</tr>
<tr>
<td>5027*</td>
<td>4</td>
<td>HH tasks all at once, vigorous</td>
</tr>
<tr>
<td>5049</td>
<td>2.5</td>
<td>food cleanup (wash dishes, put food away, fill dishwasher)</td>
</tr>
<tr>
<td>5051</td>
<td>2.5</td>
<td>stand serving food</td>
</tr>
<tr>
<td>5054</td>
<td>2.5</td>
<td>pet care, feeding, bathing, grooming</td>
</tr>
<tr>
<td>5060</td>
<td>2.3</td>
<td>shopping</td>
</tr>
<tr>
<td>5070</td>
<td>2.3</td>
<td>ironing</td>
</tr>
<tr>
<td>5090</td>
<td>2</td>
<td>laundry, wash clothes, fold/hang clothes, pack suitcase</td>
</tr>
<tr>
<td>5095</td>
<td>2.3</td>
<td>doing laundry, put away clothes, gather clothes - walking</td>
</tr>
<tr>
<td>5100</td>
<td>2</td>
<td>making beds</td>
</tr>
<tr>
<td>Code</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>5120</td>
<td>6</td>
<td>carrying furniture, heavy items, boxes and household items</td>
</tr>
<tr>
<td>5146</td>
<td>3.5</td>
<td>stand moderate effort (packing/unpacking boxes, light lifting)</td>
</tr>
<tr>
<td>5165</td>
<td>3</td>
<td>walk and gather things to leave, shut/lock doors, close windows</td>
</tr>
<tr>
<td>5170</td>
<td>2.5</td>
<td>sit play with child, light</td>
</tr>
<tr>
<td>5171</td>
<td>2.8</td>
<td>stand play with children, light</td>
</tr>
<tr>
<td>5175</td>
<td>4</td>
<td>walk/run play with children, moderate</td>
</tr>
<tr>
<td>5181</td>
<td>3</td>
<td>stand/walk hold or carry baby or small child</td>
</tr>
<tr>
<td>5184</td>
<td>1.9</td>
<td>sit child care: dressing, bathing, grooming, feeding</td>
</tr>
<tr>
<td>5186</td>
<td>3</td>
<td>stand child care: dressing, bathing, grooming, feeding, lifting</td>
</tr>
<tr>
<td>5187</td>
<td>4</td>
<td>elder care, disabled adult</td>
</tr>
<tr>
<td>5188</td>
<td>1.5</td>
<td>sit holding baby or small child</td>
</tr>
<tr>
<td>5190</td>
<td>2.5</td>
<td>sit play with animals, light</td>
</tr>
<tr>
<td>5191</td>
<td>2.8</td>
<td>stand play with animals, light</td>
</tr>
<tr>
<td>5192</td>
<td>2.8</td>
<td>walk/run playing with animals, light</td>
</tr>
<tr>
<td>5193</td>
<td>4</td>
<td>walk/run playing with animals, moderate</td>
</tr>
<tr>
<td>6030</td>
<td>3</td>
<td>automobile repair (not for work)</td>
</tr>
<tr>
<td>6040</td>
<td>3</td>
<td>carpentry, woodwork (not for work)</td>
</tr>
<tr>
<td>6101</td>
<td>5</td>
<td>home repair, heavy (painting, hang storm windows, roofing, install gutters)</td>
</tr>
<tr>
<td>6151</td>
<td>5</td>
<td>stand on a ladder working, going up and down</td>
</tr>
<tr>
<td>6160</td>
<td>3</td>
<td>home remodel (hang sheet rock, plaster, finish dry wall, painting, wallpapering)</td>
</tr>
<tr>
<td>6240</td>
<td>3</td>
<td>plumbing, wiring</td>
</tr>
<tr>
<td>7010</td>
<td>1</td>
<td>lying down, watching TV, reading</td>
</tr>
<tr>
<td>7011</td>
<td>1</td>
<td>lying down quietly awake</td>
</tr>
<tr>
<td>7020</td>
<td>1</td>
<td>sit watching television (TV, DVD, video)</td>
</tr>
<tr>
<td>7021</td>
<td>1</td>
<td>sit attend a movie/program/event/concert/meeting</td>
</tr>
<tr>
<td>7030</td>
<td>0.9</td>
<td>sleep or nap</td>
</tr>
<tr>
<td>7040</td>
<td>1.2</td>
<td>stand quietly, stand waiting in line</td>
</tr>
<tr>
<td>7060</td>
<td>1</td>
<td>lying down, talking</td>
</tr>
<tr>
<td>7062</td>
<td>1.3</td>
<td>sit texting</td>
</tr>
<tr>
<td>8010</td>
<td>5</td>
<td>carry, load, or stack wood or lumber</td>
</tr>
<tr>
<td>8020</td>
<td>6</td>
<td>chopping wood, splitting logs, using chain saw</td>
</tr>
<tr>
<td>8030</td>
<td>5</td>
<td>wheelbarrow chores, hauling branches, clearing land</td>
</tr>
<tr>
<td>8050</td>
<td>5</td>
<td>garden digging, spading, composting</td>
</tr>
<tr>
<td>8060</td>
<td>6</td>
<td>garden with heavy power tools, till a garden</td>
</tr>
<tr>
<td>8081</td>
<td>5</td>
<td>shoveling (spread dirt/mulch/rock, lay sod)</td>
</tr>
<tr>
<td>8100</td>
<td>2.5</td>
<td>mow lawn with riding mower</td>
</tr>
<tr>
<td>8121</td>
<td>5</td>
<td>mow lawn, walking (push, power, self-propelled mower)</td>
</tr>
<tr>
<td>8130</td>
<td>4.5</td>
<td>snow removal, walk with a snow blower</td>
</tr>
<tr>
<td>8141*</td>
<td>4.5</td>
<td>plant shrubs, seedlings, trees</td>
</tr>
<tr>
<td>8161</td>
<td>4</td>
<td>raking lawn (leaves, grass), including bagging</td>
</tr>
<tr>
<td>8180</td>
<td>3</td>
<td>snow removal with riding snow blower</td>
</tr>
<tr>
<td>8200</td>
<td>6</td>
<td>shovel snow by hand</td>
</tr>
<tr>
<td>8216</td>
<td>3.5</td>
<td>trim shrubs or trees</td>
</tr>
<tr>
<td>Code</td>
<td>Duration</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>8217</td>
<td>3.5</td>
<td>stand/walk, use light equipment (leaf blower, edger, weed eater)</td>
</tr>
<tr>
<td>8230</td>
<td>1.5</td>
<td>watering lawn or garden</td>
</tr>
<tr>
<td>8245</td>
<td>4</td>
<td>gardening, general (planting)</td>
</tr>
<tr>
<td>8246</td>
<td>3</td>
<td>pick fruits, vegetables, flowers, berries</td>
</tr>
<tr>
<td>8250</td>
<td>3</td>
<td>walk outside picking up yard or garden items</td>
</tr>
<tr>
<td>9005</td>
<td>1.5</td>
<td>lying down playing computer games</td>
</tr>
<tr>
<td>9010</td>
<td>1.5</td>
<td>sit playing games (cards, board games)</td>
</tr>
<tr>
<td>9011</td>
<td>1.5</td>
<td>sit playing computer games, electronic games</td>
</tr>
<tr>
<td>9012</td>
<td>2.5</td>
<td>stand playing games (charades)</td>
</tr>
<tr>
<td>9013</td>
<td>2.5</td>
<td>stand playing computer/electronic games (Wii)</td>
</tr>
<tr>
<td>9030</td>
<td>1.3</td>
<td>sit reading</td>
</tr>
<tr>
<td>9040</td>
<td>1.8</td>
<td>sit paperwork, writing, deskwork</td>
</tr>
<tr>
<td>9050</td>
<td>1.8</td>
<td>stand talking, talking on phone</td>
</tr>
<tr>
<td>9051</td>
<td>1.8</td>
<td>stand texting</td>
</tr>
<tr>
<td>9055</td>
<td>1.5</td>
<td>sit talking, sit talking on phone</td>
</tr>
<tr>
<td>9071</td>
<td>2</td>
<td>stand at sporting event, spectator</td>
</tr>
<tr>
<td>9075</td>
<td>1.8</td>
<td>sit arts and crafts</td>
</tr>
<tr>
<td>9086</td>
<td>2.4</td>
<td>stand arts &amp; crafts, hobbies</td>
</tr>
<tr>
<td>9115</td>
<td>1.5</td>
<td>sit attend a sporting event</td>
</tr>
<tr>
<td>10019</td>
<td>2.2</td>
<td>music, sit playing musical instruments (piano, guitar, wind instrument)</td>
</tr>
<tr>
<td>10040</td>
<td>4</td>
<td>music, playing drums or other percussion instrument</td>
</tr>
<tr>
<td>10125</td>
<td>3</td>
<td>music, stand playing musical instruments, guitar, marching band</td>
</tr>
<tr>
<td>11131</td>
<td>3.5</td>
<td>kneeling, working or scrubbing</td>
</tr>
<tr>
<td>11580</td>
<td>1.5</td>
<td>sit light work with light hand tools or light assembly/repair</td>
</tr>
<tr>
<td>11585</td>
<td>1.5</td>
<td>sit meetings</td>
</tr>
<tr>
<td>11590</td>
<td>2.5</td>
<td>sit operating heavy machinery or equipment (forklift, back-hoe, crane)</td>
</tr>
<tr>
<td>11600</td>
<td>2.3</td>
<td>stand/walk light work (bartender, store clerk, assembly line)</td>
</tr>
<tr>
<td>11610</td>
<td>3</td>
<td>stand/walk moderate work (waiter, patient care, stocking shelves, auto repair)</td>
</tr>
<tr>
<td>11631</td>
<td>5</td>
<td>stand/walk heavy work (moving furniture and boxes, loading/unloading trucks)</td>
</tr>
<tr>
<td>11635</td>
<td>2</td>
<td>kneeling, light effort</td>
</tr>
<tr>
<td>11770</td>
<td>1.5</td>
<td>sit computer use (email, internet, typing)</td>
</tr>
<tr>
<td>11790</td>
<td>8</td>
<td>stand/walk very heavy work (manual labor, using heavy power tools or pick/shovel, heavy objects)</td>
</tr>
<tr>
<td>11791</td>
<td>2</td>
<td>stand/walk in office or lab (talking, filing, making copies)</td>
</tr>
<tr>
<td>11792</td>
<td>3.3</td>
<td>walk moderate carrying &lt; 10 pounds or nothing</td>
</tr>
<tr>
<td>11793</td>
<td>3.8</td>
<td>walk briskly</td>
</tr>
<tr>
<td>11796</td>
<td>3</td>
<td>walk gathering things or ready to leave</td>
</tr>
<tr>
<td>11801</td>
<td>4</td>
<td>walk carrying 10-25 pounds</td>
</tr>
<tr>
<td>11805</td>
<td>4</td>
<td>walk pulling a hand-truck or pushing a cart or wheelchair</td>
</tr>
<tr>
<td>11821</td>
<td>5</td>
<td>walk carrying 25-49 pounds</td>
</tr>
<tr>
<td>11851</td>
<td>7.5</td>
<td>walk carrying 50+ pounds</td>
</tr>
<tr>
<td>12010</td>
<td>6</td>
<td>jogging/walking combination</td>
</tr>
<tr>
<td>12150</td>
<td>8</td>
<td>running or jogging</td>
</tr>
<tr>
<td>13010</td>
<td>1.5</td>
<td>sit bathing or in a hot tub</td>
</tr>
<tr>
<td>Code</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>13030</td>
<td>1.5</td>
<td>sit eating</td>
</tr>
<tr>
<td>13035</td>
<td>2</td>
<td>stand eating or drinking</td>
</tr>
<tr>
<td>13038</td>
<td>2</td>
<td>vomiting, throwing up (stomach sickness)</td>
</tr>
<tr>
<td>13041</td>
<td>2</td>
<td>selfcare: dressing/undressing, grooming (wash/shave/teeth/hair/make-up)</td>
</tr>
<tr>
<td>13046</td>
<td>1</td>
<td>sit get a haircut, have hair/nails done by someone else</td>
</tr>
<tr>
<td>14020</td>
<td>1.3</td>
<td>sexual activity</td>
</tr>
<tr>
<td>15010*</td>
<td>3.5</td>
<td>archery (not hunting)</td>
</tr>
<tr>
<td>15030</td>
<td>4.5</td>
<td>badminton, singles and doubles, general</td>
</tr>
<tr>
<td>15040</td>
<td>8</td>
<td>basketball, game play (only active periods)</td>
</tr>
<tr>
<td>15070</td>
<td>4.5</td>
<td>basketball, shooting baskets, non-game play</td>
</tr>
<tr>
<td>15080</td>
<td>2.5</td>
<td>billiards</td>
</tr>
<tr>
<td>15082</td>
<td>3</td>
<td>air hockey</td>
</tr>
<tr>
<td>15090</td>
<td>3</td>
<td>bowling</td>
</tr>
<tr>
<td>15110</td>
<td>6</td>
<td>boxing, punching bag, sparring</td>
</tr>
<tr>
<td>15135</td>
<td>5</td>
<td>children’s games (hopscotch, 4-square, dodge ball, tetherball)</td>
</tr>
<tr>
<td>15140</td>
<td>4</td>
<td>coaching football, soccer, basketball, baseball, swimming, etc.</td>
</tr>
<tr>
<td>15160</td>
<td>2.5</td>
<td>croquet</td>
</tr>
<tr>
<td>15180</td>
<td>2.5</td>
<td>darts, wall or lawn</td>
</tr>
<tr>
<td>15200*</td>
<td>6</td>
<td>fencing</td>
</tr>
<tr>
<td>15230*</td>
<td>8</td>
<td>football, game-play, touch or flag</td>
</tr>
<tr>
<td>15235</td>
<td>2.5</td>
<td>playing catch with football or baseball</td>
</tr>
<tr>
<td>15240*</td>
<td>3</td>
<td>frisbee general</td>
</tr>
<tr>
<td>15250*</td>
<td>8</td>
<td>frisbee ultimate</td>
</tr>
<tr>
<td>15270</td>
<td>3</td>
<td>golf, driving range, putting green</td>
</tr>
<tr>
<td>15285</td>
<td>4.3</td>
<td>golf, walking and pulling/carrying clubs</td>
</tr>
<tr>
<td>15290</td>
<td>3.5</td>
<td>golf, riding in cart</td>
</tr>
<tr>
<td>15300*</td>
<td>4</td>
<td>gymnastics</td>
</tr>
<tr>
<td>15310*</td>
<td>4</td>
<td>hacky sack</td>
</tr>
<tr>
<td>15350*</td>
<td>8</td>
<td>hockey, field</td>
</tr>
<tr>
<td>15360*</td>
<td>8</td>
<td>hockey, ice</td>
</tr>
<tr>
<td>15370</td>
<td>4</td>
<td>horseback riding, general</td>
</tr>
<tr>
<td>15380*</td>
<td>3.5</td>
<td>horseback riding, saddling horse, grooming horse</td>
</tr>
<tr>
<td>15410*</td>
<td>3</td>
<td>horseshoe pitching, quoits</td>
</tr>
<tr>
<td>15430</td>
<td>10</td>
<td>martial arts (judo, jujitsu, karate, kick boxing, tae kwan do)</td>
</tr>
<tr>
<td>15450*</td>
<td>7</td>
<td>kickball</td>
</tr>
<tr>
<td>15460*</td>
<td>8</td>
<td>lacrosse</td>
</tr>
<tr>
<td>15470</td>
<td>4</td>
<td>motor cycle riding, motor-cross</td>
</tr>
<tr>
<td>15480*</td>
<td>9</td>
<td>orienteering</td>
</tr>
<tr>
<td>15520</td>
<td>10</td>
<td>racquetball, game play, competitive</td>
</tr>
<tr>
<td>15530</td>
<td>7</td>
<td>racquetball, casual, pre-game warm-up</td>
</tr>
<tr>
<td>15535*</td>
<td>11</td>
<td>rock climbing, ascending rock</td>
</tr>
<tr>
<td>15551</td>
<td>10</td>
<td>rope jumping, moderate</td>
</tr>
<tr>
<td>15560*</td>
<td>10</td>
<td>rugby</td>
</tr>
<tr>
<td>Code</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>15570</td>
<td>3</td>
<td>shuffleboard, lawn bowling, bocce ball</td>
</tr>
<tr>
<td>15580</td>
<td>5</td>
<td>skateboard</td>
</tr>
<tr>
<td>15590</td>
<td>8</td>
<td>skating, roller or in-line skating (roller-blades)</td>
</tr>
<tr>
<td>15605</td>
<td>10</td>
<td>soccer, competitive, game-play</td>
</tr>
<tr>
<td>15610</td>
<td>7</td>
<td>soccer, casual, warm-up</td>
</tr>
<tr>
<td>15620</td>
<td>5</td>
<td>softball or baseball, fast or slow pitch</td>
</tr>
<tr>
<td>15630</td>
<td>4</td>
<td>officiating &amp; referee: standing/walking (softball, baseball, swimming)</td>
</tr>
<tr>
<td>15631</td>
<td>6</td>
<td>officiating &amp; referee: running the field or court (soccer, football, basketball)</td>
</tr>
<tr>
<td>15650</td>
<td>12</td>
<td>squash</td>
</tr>
<tr>
<td>15660</td>
<td>4</td>
<td>table tennis, ping pong</td>
</tr>
<tr>
<td>15670</td>
<td>4</td>
<td>tai chi</td>
</tr>
<tr>
<td>15675</td>
<td>7</td>
<td>tennis</td>
</tr>
<tr>
<td>15700</td>
<td>3.5</td>
<td>trampoline</td>
</tr>
<tr>
<td>15710</td>
<td>4</td>
<td>volleyball, game play</td>
</tr>
<tr>
<td>15720</td>
<td>3</td>
<td>volleyball, recreational, general</td>
</tr>
<tr>
<td>15725</td>
<td>8</td>
<td>volleyball, beach, game play</td>
</tr>
<tr>
<td>15730</td>
<td>6</td>
<td>wrestling</td>
</tr>
<tr>
<td>15732</td>
<td>4</td>
<td>track and field (shot, discus, hammer throw)</td>
</tr>
<tr>
<td>15733</td>
<td>6</td>
<td>track and field (high/long jump, javelin, pole vault)</td>
</tr>
<tr>
<td>15734</td>
<td>10</td>
<td>track and field (steeplechase, hurdles)</td>
</tr>
<tr>
<td>16010</td>
<td>2</td>
<td>driving a car or light truck</td>
</tr>
<tr>
<td>16015</td>
<td>1</td>
<td>riding in a airplane, car, van, or truck</td>
</tr>
<tr>
<td>16016</td>
<td>1</td>
<td>riding a bus</td>
</tr>
<tr>
<td>16020</td>
<td>2</td>
<td>flying an airplane</td>
</tr>
<tr>
<td>16030</td>
<td>2.5</td>
<td>riding a motor scooter or motorcycle</td>
</tr>
<tr>
<td>16050</td>
<td>3</td>
<td>driving a bus, heavy truck or tractor</td>
</tr>
<tr>
<td>17010</td>
<td>7</td>
<td>backpacking</td>
</tr>
<tr>
<td>17080</td>
<td>6</td>
<td>hiking, cross country</td>
</tr>
<tr>
<td>17085</td>
<td>2.5</td>
<td>bird watching</td>
</tr>
<tr>
<td>17100</td>
<td>2.5</td>
<td>walk pushing stroller, walk with children</td>
</tr>
<tr>
<td>17162</td>
<td>2.5</td>
<td>walking moderately</td>
</tr>
<tr>
<td>17165</td>
<td>3</td>
<td>walk the dog</td>
</tr>
<tr>
<td>17166</td>
<td>2</td>
<td>take dog outside in the yard - stand/walk</td>
</tr>
<tr>
<td>17200</td>
<td>3.8</td>
<td>walk briskly for exercise</td>
</tr>
<tr>
<td>17270</td>
<td>4</td>
<td>walking briskly</td>
</tr>
<tr>
<td>18010</td>
<td>2.5</td>
<td>boating, power or motor boat</td>
</tr>
<tr>
<td>18070</td>
<td>3.5</td>
<td>canoeing, rowing, for pleasure, general</td>
</tr>
<tr>
<td>18080</td>
<td>12</td>
<td>canoeing, rowing, for competition, crew or sculling</td>
</tr>
<tr>
<td>18090</td>
<td>3</td>
<td>diving, springboard or platform</td>
</tr>
<tr>
<td>18100</td>
<td>5</td>
<td>kayaking</td>
</tr>
<tr>
<td>18110</td>
<td>4</td>
<td>paddle boat</td>
</tr>
<tr>
<td>18120</td>
<td>3</td>
<td>sailing, boat/board sailing, windsurfing, ice sailing</td>
</tr>
<tr>
<td>18150</td>
<td>6</td>
<td>skiing, water</td>
</tr>
<tr>
<td>Code</td>
<td>Value</td>
<td>Activity</td>
</tr>
<tr>
<td>--------</td>
<td>-------</td>
<td>----------------------------------------------</td>
</tr>
<tr>
<td>18160*</td>
<td>7</td>
<td>ski-mobile</td>
</tr>
<tr>
<td>18200*</td>
<td>7</td>
<td>scuba diving</td>
</tr>
<tr>
<td>18210*</td>
<td>5</td>
<td>snorkeling, skin diving</td>
</tr>
<tr>
<td>18220*</td>
<td>3</td>
<td>surfing, body or board</td>
</tr>
<tr>
<td>18240</td>
<td>7</td>
<td>swim laps, freestyle, any stroke</td>
</tr>
<tr>
<td>18310</td>
<td>6</td>
<td>swim, leisurely, not laps or just standing</td>
</tr>
<tr>
<td>18355</td>
<td>4</td>
<td>water aerobics, water calisthenics</td>
</tr>
<tr>
<td>18365*</td>
<td>3</td>
<td>water volleyball</td>
</tr>
<tr>
<td>18370*</td>
<td>5</td>
<td>whitewater rafting</td>
</tr>
<tr>
<td>19030*</td>
<td>7</td>
<td>skating, ice, general</td>
</tr>
<tr>
<td>19050*</td>
<td>15</td>
<td>skating, ice, speed or competitive</td>
</tr>
<tr>
<td>19090</td>
<td>8</td>
<td>skiing, cross country</td>
</tr>
<tr>
<td>19160</td>
<td>6</td>
<td>skiing or snowboarding downhill</td>
</tr>
<tr>
<td>19180*</td>
<td>7</td>
<td>sledding, toboggan, bobsled, luge</td>
</tr>
<tr>
<td>19190*</td>
<td>8</td>
<td>snow shoeing</td>
</tr>
<tr>
<td>19200</td>
<td>3.5</td>
<td>snowmobiling</td>
</tr>
<tr>
<td>20011</td>
<td>1.3</td>
<td>sit praying or meditating/waiting quietly</td>
</tr>
<tr>
<td>20020*</td>
<td>2.5</td>
<td>stand singing</td>
</tr>
<tr>
<td>20025</td>
<td>1</td>
<td>kneeling, quiet activities</td>
</tr>
<tr>
<td>21010</td>
<td>2.5</td>
<td>riding a scooter and grocery shopping</td>
</tr>
</tbody>
</table>

Note: An asterisk (*) represents activities that were not reported by the participants.