REDUCE YOUR SIT AND BE MORE FIT: AN EXAMINATION OF SEDENTARY BEHAVIOR

by

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A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy

Middle Tennessee State University
2013

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DEDICATION

I dedicate this work to my children Dallin, Caleb, and Alaina (and any future children…). It is not a matter of seeking recognition for the things you accomplish, but seeking the spirit to influence you in what to accomplish. You can accomplish things never imaginable by remaining faithful in working toward your goals.

ACKNOWLEDGEMENTS

I would like to acknowledge Middle Tennessee State University for allowing me this opportunity to learn and grow. The administration and faculty have been very supportive and helpful during this process. I have received special support from my former and current committee chairs, Dr. Don Morgan and Dr. Jennifer Caputo. Thank you especially Dr. Caputo for your incredible turnaround time. Other committee members, Dr. Vaughn Barry and Dr. Dana Fuller, along with faculty mentor Dr. Richard Farley, have all been there to support and encourage me.

I would like to acknowledge all of the support and assistance by other graduate students and friends throughout this process. Especially, thank you Lauren Killen and Brett Davis for your help collecting validation data and thank you Saori Ishikawa and Ryan Conners for helping me collect data and lug equipment around campus.

A special thanks to all of my family that has encouraged and supported me during this process especially David and Rebecca Reece and Vic and Betty Erickson. Most importantly, I would like to thank my wife, Linda, for her love and support. She allowed me to pursue this goal and always stood by me. She has made this a great experience and one for the books!

ABSTRACT

Sedentary behavior is associated with negative health and should be accurately assessed. Due to the amount of time spent at work and the growing number of sedentary jobs, the workplace offers a natural setting to reduce sedentary behavior. The purpose of the first study in this dissertation was to validate the SWA as an instrument to measure sedentary behavior. The purpose of the second study was to use the SWA to monitor the feasibility of behavioral strategies to reduce sedentary time in the workplace. The validity of the SWA in measuring the energy expenditure of sedentary behavior and light physical activity was determined by comparing energy expenditure measurements from the SWA to indirect calorimetry (Oxycon). The feasibility of behavioral strategies to reduce sedentary time in the workplace was assessed by implementing a 1-week behavioral strategy program among sedentary female office workers titled, *Reduce Your Sit and Be More Fit*. This program included one-on-one counseling, goal setting, and self-monitoring of goals to reduce sedentary behavior.

Sedentary behavior and light physical activity energy expenditure measures from the SWA were strongly correlated with the Oxycon, $r(20) = .90$, $p < .001$, ICC = .90, 95% CI [.699, .966]. The SWA significantly under predicted energy expenditure while standing with no movement ($p = .002$), performing office work while sitting ($p < .001$), and performing office work while standing ($p < .001$). In addition, the SWA correctly classified sedentary, light, and moderate physical activity 88.6% of the time. Overall, these results demonstrated the SWA is a valid instrument to measure sedentary behavior and light activity. In the second study, office workers who received the intervention to reduce sedentary behavior had a greater decrease in sedentary behavior

(p = .023), a greater increase in light physical activity (p = .027), a greater increase in average occupational energy expenditure, (p = .032), and a greater increase in average occupational MET level (p = .036) compared to the control group. Based on these results, it was feasible to reduce sedentary time in the workplace by implementing behavioral strategies.

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CHAPTER I

DISSERTATION INTRODUCTION

There appear to be physiological changes that occur specifically as a result of inactivity or sedentary behavior which have unique pathways compared to the changes resulting from moderate to vigorous activity (Hamilton, Hamilton, & Zderic, 2004). The study of these pathways is often referred to as the study of "inactivity physiology" or the study of "sedentary physiology" (Hamilton et al., 2004; Tremblay, Colley, Saunders, Healy, & Owen, 2010).

Sedentary behavior has often been defined as movement not meeting the recommended guidelines of moderate to vigorous exercise for a given duration. However, activity less than moderate levels can be further classified into light activity and sedentary behavior, defining sedentary behavior distinctly from light activity (Pate, O'Neil, & Lobelo, 2008). This definition of sedentary behavior includes a postural position of lying or sitting with a metabolic equivalent task (MET) of ≤ 1.5 (Tremblay et al., 2010).

Objective and subjective measurement tools to identify sedentary behavior or light activity have been developed to relate these behaviors with health consequences or diseases (Healy, Matthews, Dunstan, Winkler, & Owen, 2011; Katzmarzyk, Church, Craig, & Bouchard, 2009; Owen, Healy, Matthews, & Dunstan, 2010; Tremblay et al., 2010). Common measurement tools include the activPAL professional accelerometer (PAL Technologies Ltd., Glasgow, UK), the ActiGraph accelerometer (ActiGraph LLC, Pensacola, FL), and the Bouchard Activity Record (BAR; Bouchard et al., 1983). While the activPAL and the BAR report similar amounts of time for sedentary and light activity (except when standing), the ActiGraph tends to over measure sedentary behavior (i.e., <100 activity counts per minute) on average by approximately 2 to 3 hours a day compared to activPAL and BAR measurements (Hart, Ainsworth, & Tudor-Locke, 2011).

The objective measurements from the activPAL and ActiGraph focus on measuring posture and activity counts to define sedentary behavior, respectively. However, sedentary behavior and light activity are also defined by MET level. Therefore, when measuring sedentary behavior or light activity, it is equally important to objectively estimate energy expenditure. Energy expenditure during sedentary behavior and light activities is commonly referred to as non-exercise activity thermogenesis (NEAT) and plays a role in the study of sedentary physiology (Hamilton, Hamilton, & Zderic, 2007). Using an instrument such as the SenseWear™ armband (SWA; BodyMedia, Inc., Pittsburgh, PA) to measure sedentary behavior and light activity may help to explain how low daily NEAT attributes to sedentary disease. Although the SWA has been validated to estimate daily activity energy expenditure, research has not been conducted to validate this instrument as a measure of sedentary behavior. Welk, McClain, Eisenmann, and Wickell (2007) suggested the SWA should be validated using precise transition points between activities of daily living, mostly comprising sedentary behavior and light activity.

Once able to capture both postural and energy expenditure measures of sedentary behavior and light activity, researchers can better measure the effects of interventions to reduce the time of sedentary behavior. Only a few researchers have attempted to objectively measure reductions in sedentary time (Gardiner, Eakin, Healy, & Owen, 2011; Kozey-Keadle, Libertine, Staudenmayer, & Freedson, 2012; Otten, Jones, Littenberg, & Harvey-Berino, 2009). In addition, despite innovative ideas to reduce sedentary time such as walk-and-work stations (Levine & Miller, 2007; Thompson, Foster, Eide, & Levine, 2007), portable pedal machines (Carr, Walaska, & Marcus, 2011), portable stepping devices (McAlpine, Manohar, McCrady, Hensrud, & Levine, 2007), stability balls (Faries, Bartholomew, & McCalister, 2011), and standing stations (Gilson, Suppini, Ryde, Brown, & Brown, 2012), Chau et al. (2010) concluded more research implementing these types of interventions needs to be conducted in order to determine their effectiveness in reducing sedentary behavior in the workplace. After identifying effective strategies to reduce sedentary behavior, researchers will be able to perform longer duration studies and ultimately measure changes in health outcomes.

There is a call for researchers to identify effective tools to measure sedentary behavior (Pate et al., 2008) and discover effective interventions that reduce sedentary behavior (Chau et al., 2010; Kozey-Keadle et al., 2012). Only after this is accomplished can health outcomes related to reducing sedentary time be determined.

Purpose

The investigations within this dissertation are intended to determine if the SWA can be used to accurately determine energy expenditure during sedentary and light activities and to determine the feasibility of reducing sedentary time and increasing light activity among sedentary office workers. The purpose of the first study is to validate the SWA for the measurement of sedentary and light activities using two methods of validation. The first method is to validate energy expenditure using open-circuit, indirect calorimetry as the criterion. We hypothesize energy expenditure during sedentary behavior and light activity measured by the SWA is strongly correlated to energy expenditure measured by indirect calorimetry. The second method will evaluate the construct validity of the SWA and determine if the SWA can be used to differentiate between the energy expenditure of sedentary behavior and light activity. We hypothesize that the SWA is sensitive enough to detect differences in energy expenditure between sedentary behaviors and light activities.

The purpose of the second study is to identify the effect of behavioral strategies (i.e., education, one-on-one counseling, self-monitoring) promoting less sedentary time in the workplace on estimated energy expenditure and sedentary time. Using MET level cut points for sedentary behavior and light activity, we hypothesize that behavioral strategies to reduce sedentary behavior in the workplace will result in less sedentary time and increased light activity time at the workplace. We also hypothesize that total energy expenditure (kcals) will increase in the workplace as a result of behavioral strategies aiming to reduce sedentary time.

Significance of Studies

A validated tool that can be used to identify and measure the difference in energy expenditure between sedentary and light activities will allow researchers to implement interventions of light activity. After measuring the validity of the SWA, the effect of behavioral strategies on energy expenditure and sedentary behavior in the workplace will be identified. If found to be feasible and effective, these behavioral strategies could be implemented in the workplace to help reduce sedentary time. The ability to identify an effective intervention to increase energy expenditure and decrease sedentary time in the workplace lends great potential to identifying changes in health variables and health risks associated with sedentary behavior in future studies.

CHAPTER II

REVIEW OF THE LITERATURE

This review begins with an explanation of sedentary behavior and its evolving definition in the literature. Next, this review will help clarify the specific use of measurement tools to distinguish between sedentary behavior and low intensity activity. Following this, the prevalence and consequences of sedentary behavior are reviewed along with disease outcomes and possible metabolic pathways. The review then transitions into an overview of the measurement tools available to assess sedentary behavior and light activity with attention also devoted to the application of the corresponding measurement unit from each tool. After this section, the review contains an evaluation of intervention studies that have identified sedentary behavior and light activity. The literature review concludes by revisiting the need for appropriate measurement tools of sedentary behavior and light activity and the importance of investigating the effects of sedentary and light activity through intervention studies.

Defining Sedentary Behavior

Exercise physiology has typically addressed the effects of moderate and vigorous exercise as they relate to health outcomes. More recently, the study of sedentary physiology or inactivity physiology has begun to identify the effects of sitting and low energy expenditure, expressed by separate intensities of sedentary behavior and light activity, on health outcomes (Hamilton, Healy, Dunstan, Zderic, & Owen, 2008; Hamilton et al., 2007; Levine, Vander Weg, Hill, & Klesges, 2006; Owen et al., 2010;

Pate et al., 2008; Tremblay et al., 2010). This distinction between exercise physiology and inactivity physiology can only be made when sedentary behavior is defined and measured correctly. It is not simply enough to treat sedentary behavior as a lack of higher intensities of physical activity or exercise because its attributes are distinct from physical activity (Owen et al., 2010). It should be identified and researched independently of higher intensities due to its unique measurement process, nature, and physiology (Tremblay et al., 2010).

Sedentary behavior is namely defined by engaging in a postural position of lying or sitting, while in a state of low energy expenditure (Owen et al., 2010). Owen et al. (2010) explained that the Latin route of sedentary means "to sit" and common domains associated with sitting behaviors are often related to the work place, home, transportation, and leisure time. Although the definition of sedentary behavior includes the behavior of sleeping, researchers have yet to evaluate sleeping as a sedentary behavior and, instead, have focused on sedentary behaviors during waking hours. Common behaviors with sedentary energy expenditures, which take place while in a sedentary posture, are watching television, working at a desk or on a computer, or sitting in a vehicle (Ainsworth et al., 2011; Owen et al., 2010). It is inappropriate to define sedentary behavior by merely identifying one sedentary behavior (e.g., time spent watching television). Researchers attempting to draw conclusions about the effects of sedentary behavior should instead capture several sedentary behaviors (Clark et al., 2009; Pate et al., 2008). For example, if the amount of time spent watching television is the solitary variable used to define sedentary behavior then the definition of sedentary behavior may be misrepresented because it only embraces a portion of all actual sedentary time. One could be misclassified as not being sedentary simply because time spent watching television is minimal when in actuality the time spent in other sedentary pursuits such as driving, reading, or writing is high.

Sedentary behavior has also often been defined as not meeting recommended physical activity or exercise guidelines. These guidelines usually include participating in aerobic exercise of moderate to vigorous intensity for a given duration and frequency. However, if researchers classify individuals as sedentary, not by measuring the actual time spent in sedentary behavior, but by whether or not exercise guidelines are met, they are actually defining sedentary behavior as time not spent in moderate or vigorous activity (Pate et al., 2008). This definition of sedentary behavior inappropriately combines different levels of intensity. In addition, simply falling short of physical activity guidelines does not allow for postural assessment specific to being sedentary.

Sitting has an expenditure of 1.0-1.5 METs and can be used to define sedentary behavior (Ainsworth et al., 2011; Pate et al., 2008). Moderate intensity includes activities with an absolute intensity of 3.0-5.9 METs and vigorous activities of 6.0-8.7 METs (American College of Sport Medicine [ACSM], 2011). These definitions of various intensity levels illustrate the existence of an intensity level above sedentary, but lower than moderate. This other intensity level, known as light activity, is frequently inappropriately grouped as sedentary behavior (< 3.0 METs) in the literature (Pate et al., 2008). Light activity includes activities other than sedentary behaviors and has a metabolic expenditure between 1.6 METs and 2.9 METs (Pate et al., 2008). By understanding the different categories of intensities often used in the literature with their equivalent metabolic expenditures, it is clear to see that anything less than moderate intensity can be defined as either light activity or sedentary.

Therefore, appropriately defining sedentary behavior incorporates both postural position of sitting or lying while in a state of low energy expenditure. It is important when assessing sedentary behavior to use forms of measurement (e.g., METs, activity counts, and time sitting or lying) that allow sedentary behavior to be assessed distinctly from light activity, just as moderate activity is distinct from vigorous. In this way, it is possible to draw conclusions about the effects of sedentary behavior on health.

Prevalence of Sedentary Behavior

Studies show that throughout the course of a day, more than 90% of the time is spent in sedentary behavior or light activity (Gardiner et al., 2011; Kozey-Keadle et al., 2012). On average, a child or adult US civilian spends more than half (54.9%) of their waking time being sedentary (<100 counts per minute; Matthews et al., 2008). This is equivalent to approximately 7.7 hours per day. Among all age groups, the most sedentary groups are adolescents, 16-19 years of age, and adults, 60-85 years of age (Matthews et al., 2008). These age groups spend nearly 60-65% (i.e., upwards of 9.5 hours per day) in sedentary pursuits (Bankoski et al., 2011; Matthews et al., 2008).

Up to age 30 years, females spend significantly more time being sedentary than males, but from 30-59 years there is no difference in sedentary time between males and females (Matthews et al., 2008). From age 60 years and older, males are more sedentary than females (Matthews et al., 2008).

When compared by population, Mexicans overall are significantly less sedentary than both Blacks and Whites (Matthews et al., 2008). Among special populations, bariatric surgery candidates spend an alarming rate of 10.9 $\pm$ 2.1 hours a day in sedentary behavior ($\leq$ 1.5 METs; Bond et al., 2011). In addition, bariatric surgery candidates with a body mass index (BMI) of 50 kg/m^2 are likely to be sedentary nearly 1 hour longer than those with a BMI between 35 kg/m^2 and 49.9 kg/m^2 (Bond et al., 2011).

Related Health Consequences of Sedentary Behavior

While there has been much research on the health benefits and dose-response relationship of physical activity and exercise, there has been less research on the health consequences and dose-response relationship of sedentary behavior (ACSM, 2011). However, this body of knowledge surrounding sedentary or inactivity physiology is quickly growing with supporting evidence of its harmful effects on health (Levine et al., 2006; Owen et al., 2010; Pate et al., 2008). These harmful effects include an increased risk of mortality (Dunstan et al., 2010), obesity (Sugiyama, Healy, Dunstan, Salmon, & Owen, 2008), detrimental associations with cardio-metabolic biomarkers (Healy, Matthews, et al., 2011), blood glucose levels (Healy et al., 2007), type II diabetes (Hu, Li, Colditz, Willett, & Manson, 2003), and the metabolic syndrome (Bertrais et al., 2005; Dunstan et al., 2005; Ford, Kohl, Mokdad, & Ajani, 2005; Gao, Nelson, & Tucker, 2007; Healy, Wijndaele, et al., 2008).

In particular, Katzmarzyk et al. (2009) identified a dose-response relationship of sedentary behavior (defined as self-reported sitting time) with mortality from all causes and cardiovascular disease. The dose-response was defined into quintiles of sitting almost none of the time, one fourth of the time, one half of the time, three fourths of the time, and almost all of the time. There was a significant positive trend with mortality from all causes and mortality from cardiovascular disease as sitting time increased. It is important to note that these significant trends remained even after controlling for physical activity levels. This provides evidence that sedentary behavior, as defined by sitting time, has its own unique pathway(s) related to mortality by cardiovascular disease and all causes.

Sedentary behavior is also independently related to obesity. In an effort to better capture the effect of sedentary behavior on obesity, Sugiyama et al. (2008) used a self-report of six leisure time sedentary behaviors to identify sedentary time, instead of simply using one variable (e.g., screen time). Although time spent in sedentary behavior at work was not accounted for, leisure time sedentary behavior was classified above and below the median of 206 minutes (~3.5 hours). Sufficiently active adults (150 min or 2.5 hours a week in at least moderate physical activity) that spent 206 minutes or more of their leisure time in sedentary pursuits were just as likely to be overweight or obese as individuals that were not sufficiently active (less than 2.5 hours per week) and had fewer than 206 minutes of sedentary behavior. In addition, those who were both highly sedentary and not sufficiently physically active had the highest risk of being overweight or obese. These results identify sedentary time as a risk to obesity, independent of physical activity; just as insufficient physical activity is an independent risk to obesity. Furthermore, the combination of high leisure sedentary time and insufficient leisure physical activity time may lead to an even greater risk of obesity.

To help support the notion that sedentary behavior has unique pathways that lead to health consequences, it is important to objectively control for physical activity as in the examples above. By doing so, better judgment can be made as to the cause of the relationship. The National Health and Nutrition Examination Survey (NHANES) included accelerometry measurements to identify periods of little movement (which relates to sedentary behavior), light movement (activity), moderate movement (activity), and vigorous movement (activity). Because posture was not assessed, sedentary behavior was defined in minutes by including all minutes in which activity counts were less than a given cut-point. While measuring a range of intensities, accelerometry allows researchers using these data to better understand the effects of sedentary behavior, by controlling for activity of different intensity levels. Using NHANES data from 2003 to 2006, associations between total sedentary and certain cardio-metabolic biomarkers have been identified, independent of exercise time (Healy, Matthews, et al., 2011). Specifically, cardio-metabolic biomarkers associated with sedentary time include increased waist circumference, decreased HDL-cholesterol, increased C-reactive protein, increased triglycerides, increased insulin, decreased homeostasis model assessment for insulin sensitivity (HOMA-%S), and increased homeostasis model assessment for β-cell function (HOMA-%B). Among these, triglycerides and insulin have the strongest associations with being sedentary (i.e., low movement counts).

Another variable independently associated with objectively measured sedentary time is an oral glucose tolerance test of 2-hour plasma glucose (Healy et al., 2007). This is an important variable because blood glucose is associated with type 2 diabetes, risk of all-cause mortality, and cardiovascular disease mortality (Unwin, Shaw, Zimmet, & Alberti, 2002). Healy et al. (2007) were the first to identify a positive association between sedentary time (accelerometer counts/min <100; average hours/day) and blood glucose and a negative association between light activity (counts/min 100-1951) and blood glucose using objective measurements. These results explain both a health risk associated with sedentary behavior and a possible benefit of replacing sedentary time with light activity. Interestingly, only 2-h plasma glucose and not fasting plasma glucose were significantly associated with sedentary time. This suggests sedentary and light activity may impact peripheral insulin resistance more than hepatic glucose output and insulin secretion as metabolic pathways for blood glucose levels (Unwin et al., 2002).

Although a number of studies have helped to identify a relationship between sedentary behavior and light activity with type 2 diabetes (Hu et al., 2003) and metabolic syndrome (Bertrais et al., 2005; Dunstan et al., 2005; Ford et al., 2005; Gao et al., 2007; Healy, Wijndaele, et al., 2008), few studies exist with objective measurements of sedentary time. Healy, Wijndaele, et al. (2008) used accelerometry to objectively measure sedentary time (<100 counts/min) and light activity time (100-1951 counts/min). Sedentary time was positively associated with waist circumference, triglycerides, and a clustered metabolic risk score (computed from waist circumference, triglycerides, HDL cholesterol, systolic blood pressure, diastolic blood pressure, and fasting plasma glucose), and light activity was positively associated with waist circumference and the clustered metabolic risk score. The authors explained that, on average, for every 10% increase in sedentary time, waist circumference increased 3.1 cm. Furthermore, sedentary time was highly negatively associated with light-intensity time ($r = -.96$), suggesting again that metabolic benefits may be achieved by replacing sedentary time with light activity time.

When sedentary time is replaced with standing or light activity, non-exercise activity thermogenesis (NEAT) increases (Hamilton et al., 2007; Levine et al., 2005; Levine et al., 2006). Energy expenditure increases when NEAT increases (e.g., more standing or walking) because contractile activity of skeletal muscles is required (Hamilton et al., 2007). Therefore, one of the possible metabolic pathways for health consequences of obesity and waist circumference related to sedentary behavior is a result of low energy expenditure (Levine, Schleusner, & Jensen, 2000; Levine et al., 2005).

In mice, the lack of skeletal muscle activation while sedentary is also believed to account for the 90-95% decrease of lipoprotein lipase (LPL) activity compared to low ambulatory conditions (Bey & Hamilton, 2003; Hamilton et al., 2004). This identifies a possible metabolic pathway for coronary heart disease from sedentary behavior (Bey & Hamilton, 2003; Hamilton et al., 2004). This enzyme is essential to help hydrolyze triglycerides (Hamilton et al., 2004) and when highly active, appears to help decrease diet-induced atherosclerosis and hypercholesterolemia (Fan et al., 2001), decrease diabetic hyperlipidemia (Myers et al., 2002), and decrease diet-induced adiposity (Jensen et al., 1997). The sensitivity of LPL activity to sedentary behavior occurs 4-6 hours after being sedentary with more than half of LPL activity ceasing (Bey & Hamilton, 2003).

In summary, the evidence mounting against sedentary behavior's negative impact on health has influenced exercise prescription guidelines to issue specific recommendations to reduce sedentary behavior, independent of exercise guidelines (ACSM, 2011). Although the dose-response relationship of sedentary behavior is still in its infant stages, one study suggests that sitting half of the day results in an increased risk of all cause mortality with an even greater risk as sitting time increases to three quarters of the day and most of the day (Katzmarzyk et al., 2009). An increase in all cause mortality may be in part explained by the association of cardio-metabolic markers with sedentary behavior (Dunstan et al., 2005; Healy et al., 2007; Healy, Matthews, et al., 2011; Hu et al., 2003). With primary focus on leisure time sedentary behavior, approximately 3.5 hours may indicate a cut-point of sedentary behavior related to being overweight or obese (Sugiyama et al., 2008). This time frame of 3.5 hours is also similar to how long it takes to decrease LDL activity when sedentary (Bey & Hamilton, 2003). A decrease in LDL activity is a major metabolic pathway of disease distinct to sedentary behavior and may help explain the association of some health consequences related to sedentary behavior (Bey & Hamilton, 2003). Furthermore, the 3.1 cm increase in waist circumference for every 10% increase in sedentary time (Healy, Wijndaele, et al., 2008) may be a result of low energy expenditure (Levine et al., 2000; Levine et al., 2005). In order to continue this discovery of the dose-response relationship of sedentary behavior, the use of effective measurement tools must be applied.

Measurement Tools of Sedentary Behavior

Subjective and objective measurements. It is recommended that sedentary behavior captured on a given population should include two types of measurements. These measurements include self-report measures and device-based measurements (Healy, Clark, et al., 2011). Self-report measures are typically subjective and device-based measurements objective.

First, self-report questionnaires can be helpful in identifying domains of sedentary behavior and information on specific sedentary behavior (Healy, Clark, et al., 2011). While self-report questionnaires have helped identify a relationship between sedentary behavior and health consequences, questionnaires generally lack the ability to comprehensively evaluate sedentary behavior (Pate et al., 2008). For example, using a questionnaire, Hu et al. (2003) found associated health benefits during a 6-year follow-up with women who increased light activity by 2 hours a day. These health benefits included a 9% reduction in obesity and a 12% reduction in diabetes (Hu et al., 2003). Recently, the self-report BAR has been compared to objective measurements of sedentary behavior. In general, although the BAR shows convergence of measuring sedentary time with an objective measurement, it is likely that the “smoothing” effect of the BAR (i.e., only measuring every 15 minutes) limits its sensitivity to detect changes in sedentary time and behavior patterns (Hart, et al., 2011).

Second, the objective device-based instrument should be sensitive in monitoring sedentary time and patterns of sedentary behavior (Healy, Clark, et al., 2011). When selecting a device to measure time and patterns of sedentary behavior it should be a valid instrument compared to a criterion measure of sedentary time. A criterion measure of time spent in sedentary behavior (i.e., sitting or lying) is direct observation of postural position while tracking light movement; tracking light movement allows sedentary time to be differentiated from light activity (Fruin & Rankin, 2004; Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011). Although the observation of postural position can estimate energy expenditure according to the physical activity compendium, it is not the criterion measure of metabolic expenditure (Ainsworth et al., 2011). Instead, calorimetry has often been used as a criterion measure of metabolic expenditure at rest and different intensity levels (Ainsworth et al., 2011; Fruin & Rankin, 2004; Jakicic et al., 2004). Because sedentary behavior is often defined using time in sedentary posture and/or low metabolic expenditure, effort should be made to use valid and reliable instruments that are sensitive to these measurements.

Less effective tools to measure sedentary behavior. There are multiple ways to determine sedentary time, depending on the device selected. The device may measure the amount of accumulated time spent sitting, time with little activity counts based on a cut point, or time spent under 3.0 METs. An inappropriate device does not differentiate sedentary time from light activity. For example, although the use of a pedometer can be used as a tool to help determine if an individual is generally sedentary (< 5,000 steps/day), the typical pedometer cannot determine the amount of sedentary time or pattern of sedentary behavior (Tudor-Locke, Hatano, Pangrazi, & Kang, 2008). Furthermore, if an individual is sedentary throughout the day, but still accumulates more than 5,000 steps because of 30 minutes of exercise, a pedometer would not detect this individual as being sedentary. In this case, a pedometer would fail to capture the true sedentary behavior of an "active couch potato," one who meets the recommendations for physical activity, but is sedentary the rest of the day (Healy, Wijndaele, et al., 2008; Owen et al., 2010).

Unlike most pedometers, a heart rate monitor has the ability to track a pattern. Specifically, heart rate monitors capture fluctuating intensities and can be used to predict energy expenditure based on heart rate. However, it is important to consider other factors besides intensity (e.g., emotional stress, heat stress, humidity, posture, dehydration, illness, fitness level, stimulants) that can influence heart rate (Christensen, Frey, Foenstelien, Aadland, & Refsum, 1983; Davidson, McNeill, Haggarty, Smith, & Franklin, 1997; Melanson, Freedson, & Blair, 1996; Montoye, Kemper, Saris, & Washburn, 1996; Spurr et al., 1988). This makes it difficult to determine the true cause of heart rate fluctuation in a free-living environment, jeopardizing heart rate-based intensity classifications. In addition, using a heart rate monitor to measure sedentary behavior and low-intensity activity based on estimated energy expenditure is also inappropriate due to the lack of linearity of heart rate and energy expenditure at low-intensities (Ainslie, Reilly, & Westerterp, 2003). Thus, during a 24-hour period which includes large amounts of sedentary and light activity, this nonlinearity at low intensities influences the error of sedentary and lightly active estimated energy expenditures (Christensen et al., 1983; Davidson et al., 1997; Livingstone, 1997).

More effective tools to measure sedentary behavior. Currently, few tools exist to objectively measure time in sedentary behavior. The two most widely known tools are the activPAL (PAL Technologies Ltd., Glasgow, UK) and the ActiGraph (ActiGraph LLC, Pensacola, FL) accelerometers. The activPAL can be used to measure time in a sedentary posture, standing, or walking, while the ActiGraph measures time in sedentary behavior or light activity not by posture, but by using activity count cut points. It is recommended that in addition to these tools, other instruments that may already be developed or waiting to be developed could improve the measurement of sedentary behavior (Pate et al., 2008).

The activPAL Professional accelerometer has been validated against direct observation for time in the sedentary behavior of sitting/lying (does not differentiate between sitting and lying) and time in light activities of standing and walking (Abraham, McClain, Pettee, & Tudor-Locke, 2007; Grant, Ryan, Tigbe, & Garnat, 2006). Kozey-Keadle et al. (2011) suggested that even though the activPal may slightly underestimate sedentary time by 2.8%, this instrument is still sensitive enough to detect reductions in sitting time, unlike the ActiGraph. Besides measuring time in a given posture (i.e., thighs parallel or perpendicular with the ground) and activity counts, the activPAL also estimates energy expenditure. Although the activPAL can estimate energy expenditure, it is based off step counts instead of the commonly used activity counts in accelerometers (Harrington, Welk, & Donnelly, 2011). It is recommended that further modification of the current equation determining energy expenditure be explored using activity counts (Harrington et al., 2011). Additionally, because the activPAL is used to measure sedentary behavior, validation for energy expenditure should also be done specific to sedentary behavior and light activity.

Even though the ActiGraph accelerometer has recently been shown to not be the best tool to measure sedentary behavior (because of its lack of sensitivity in detecting reductions in sedentary time and its inability to detect postural position), researchers have still been able to gain insight by using activity cut points derived from energy expenditure and direct observation (Hart et al., 2011; Kozey-Keadle et al., 2011). Freedson, Melanson, and Sirard (1998) documented that activity counts registered by the ActiGraph accelerometer equivalent to or less than 1,951 counts per minute corresponded to a MET value of less than 3.0. Thus, using the ActiGraph accelerometer, time recorded with less than 1,951 counts per minute can be interpreted as sedentary and light activity. In order to appropriately differentiate sedentary and light activity, additional activity cut points have also been identified. Through comparison of direct observation and actual movement of activity, it has been determined that the ActiGraph accelerometer may best define sedentary behavior by using the threshold of 150 counts per minute (Kozey-Keadle et al., 2011). This is slightly different than the commonly used cut point of 100 counts per minute (Matthews et al., 2008). Defining sedentary time using a cut point of 100 counts per minute may significantly underestimate sedentary time (Kozey-Keadle et al., 2011).

Despite attempts to use both the activPAL and ActiGraph to correlate sedentary outcome measures with energy expenditure, alone, neither tool appears to be a valid instrument of sedentary or light activity energy expenditure. This is a critical point because part of the definition of sedentary behavior and light activity is based off of energy expenditure (Owen et al., 2010; Pate et al., 2008). In order for a tool to be validated for this function, it must be compared to a criterion measure of energy expenditure. The criterion measure for energy expenditure is calorimetry.

Calorimetry can be determined directly or indirectly. Direct calorimetry is done in a chamber where the amount of heat lost or gained by a system can be measured (Battley, 1995; Jequier & Schutx, 1983). However, due to its cost, management, and ability to simulate free-living activity it is not commonly used (Battley, 1995). Indirect calorimetry does not directly measure the heat lost or gained by a system, but determines it through calculation (Battley, 1995). One form of indirect calorimetry is doubly labeled water (DLW: Ainslie et al., 2003). Using DLW allows for assessment of energy expenditure in a free living environment over a period of time (usually 4-21 days), but does not allow for patterns, intensity, duration, or frequency of sedentary behavior or physical activity to be monitored (Ainslie et al., 2003). Indirect calorimetry systems are categorized as closed or open circuits and measure oxygen consumption (O_2) and carbon dioxide (CO_2) production (Ainslie et al., 2003). A closed-circuit system usually requires respiration from a pure oxygen source, while mixed with previously expired CO_2 (Ainslie et al., 2003). An open-circuit system is typically performed in one of two ways, breathing under a ventilated hood simulating outside air or having direct access to breathe outside air (Ainslie et al., 2003). Either of these indirect calorimetry systems (i.e., open-circuit or closed-circuit) can be used to measure energy expenditure during sedentary behavior or light activity, but more comfortable and accessible measurements when movement is involved may come from using an open-circuit with direct access to breathing outside air (Ainslie et al., 2003). In addition, portable indirect calorimetry systems with metabolic gas analyses systems have been developed in order to better measure energy expenditure in various environments and a range of exercises (Ainslie et al., 2003; Macfarlane, 2001).

Using calorimetry, both the Intelligent Device for Energy Expenditure and Physical Activity (IDEEA) and the SWA have shown to be valid instruments in expressing energy expenditure at both rest and during physical activity (Fruin & Rankin, 2004; Johannsen et al., 2010; Papazoglou et al., 2006; St-Onge, Mignault, Allison, & Rabasa-Lhoret, 2007; Welk et al., 2007). While the IDEEA monitor has also shown high accuracy of detecting the type of most fundamental movements with accurate energy expenditure, the SWA estimates energy expenditure best when the type of activity is known (Andre et al., 2006; Welk et al., 2007). The IDEEA monitor has been shown as a valid measure of activities of daily living, but it is not the most practical because of the necessary adhesion of wires leading to the limbs when worn (Welk et al., 2007). The SWA can be easily worn on the upper right arm and may be more practical for long term wear and monitoring. The equations used to derive energy expenditure use multiple key data obtained from the several sensors on the SWA device (i.e., accelerometer, skin temperature sensor, galvanic skin response, and heat flux [Andre et al., 2006]). Even though the SWA has been validated at rest and for a number of moderate and vigorous activities, special attention has not been given to validate the measurement of sedentary behavior and light activity. If validated during sedentary behavior and light activity, the SWA could prove a valuable tool in sedentary physiology by providing energy expenditure measurements on an individual basis rather than general estimations for the population using the Physical Activity Compendium. In addition, knowing individual energy expenditure measurements can help monitor part of the key definition of sedentary behavior and light activity.

The key to using the best instrument(s) to measure sedentary behavior is to identify the outcome measure of interest. Sedentary behavior can be defined by specific behavior, sitting time, inactivity time (activity counts), and energy expenditure (Pate et al., 2008). Consequences related to sedentary behavior appear to have multiple pathways relating to the specific components that define sedentary behavior such as actual behavior (Healy, Dunstan, et al., 2008), sitting time (Bey & Hamilton, 2003), and low energy expenditure (Hamilton et al., 2007). Currently, the most practical instrument to capture sedentary posture (sitting/lying), that is also sensitive enough to detect changes in sedentary behavior, is the AcivPAl (Kozey-Keadle et al., 2011). However, if the outcome measure of interest is energy expenditure, the SWA may be the most practical, pending further validation with sedentary-specific behavior and light activity. Being able to use the measurement tool(s) most applicable to the research question will allow researchers to conduct the proper interventions and accurately measure the outcome variables of interest.

Reducing Sedentary Time

With mounting evidence of the health consequences related to sedentary behavior, health guidelines have recently begun to include recommendations to avoid long periods of time spent in sedentary pursuits and to alert health and fitness professionals to be aware of the amount of time clients are sitting (ACSM, 2011). With these recommendations for the public, there is also a recommendation for researchers to focus on identifying the effects of reducing sedentary behavior and increasing light activity (Chau et al., 2010; Hamilton et al., 2008; Owen et al., 2010; Tremblay et al., 2010). Overall, few studies have aimed to measure reductions in sedentary time. These studies have included interventions and strategies both in the workplace and not specific to the workplace.

Interventions not specific to the workplace. Kozey-Keadle et al. (2012) implemented a 1 week intervention to decrease sedentary time not just during work hours, but throughout all waking hours of the day (16-hours). The researchers suggested activities to decrease sedentary time at home, at work, and during recreation and transportation. Overall, the activPAL was able to detect a 5% reduction (48 minutes) in total sedentary time (time spent sitting or lying) among sedentary, overweight, non-exercising office workers. Although the intervention did decrease sedentary time, this reduction is unlikely able to produce health benefits according to the authors.

The results from Kozey-Keadle et al. (2012) were similar to an intervention among adults 60 years and older who received face-to-face goal-setting and consultation with mailed feedback (Gardiner et al., 2011). This tailored approach to reduce sedentary time, assessed over 6 days, reduced sedentary time (minutes <100 count per minute) by

3.2% as assessed by the ActiGraph GT1M accelerometer. This reduction occurred mostly after 10:00 AM while breaks in sedentary time increased 4% between 7:00 PM and 9:00 PM. In another study, Otten et al. (2009) saw similar results as well with a 3.8% decreased in sedentary time (time spent in 1.5 METs or less). Otten et al. (2009) also objectively examined the effect of reducing television viewing by 50% on energy expenditure using the SWA. In this case, the intervention group with reduced television viewing significantly increased energy expenditure (119 kcal/day) compared to the control group (-95 kcal/day).

These studies suggest it is possible for adults to decrease sedentary time, increase the number of breaks in sedentary time, and reduce specific sedentary behaviors to increase energy expenditure throughout the day (Gardiner et al., 2011; Kozey-Keadle et al., 2012; Otten et al., 2009). It is not possible at this time to determine if these studies reduced enough sedentary time to impact health. Nevertheless, if similar interventions were implemented during hours adults are most sedentary, the same intervention may result in greater reductions of sedentary behavior.

Interventions and strategies in the workplace. In an attempt to reduce sedentary time in an office or workplace setting, researchers have evaluated the feasibility and energy expenditure of “walk-and-work” stations (Levine & Miller, 2007; Thompson et al., 2007), the feasibility of using a portable pedal exercise machine to reduce sedentary time (Carr et al., 2011), the energy expenditure of using a portable stepping device (McAlpine et al., 2007), the use of sitting on a stability ball (Beers, Roemmich, Epstein, & Horvath, 2008; Faries et al., 2011; Gregory, Dunk, & Callaghan, 2006; Kingma & van Dieen, 2009; McGill, Kavcic, & Harvey, 2006), and the feasibility and energy expenditure of standing interventions (Gilson et al., 2012; Levine et al., 2000; Speck, 2011; Speck & Schmitz, 2009).

A “walk-and-work” station allows an office worker to replace sitting time with light activity, walking at a self-selected pace on a treadmill (Levine & Miller, 2007). Replacing sitting time with light activity requires energy expenditure to increase. Employing indirect calorimetry, Levine and Miller (2007) determined energy expenditure could increase approximately 100 kcal for every hour spent walking (1.1 mph) in otherwise sedentary obese adults, or from 1.75 (kcal/fat-free mass[kg]/h) to 4.65 (kcal/kg/h). The feasibility of a walk-and-work station among nurses, clinical assistants, secretaries, and appointment secretaries (N = 8) to increase daily walking has shown positive feedback and an average increase of steps from 2,200 to 4,200 during working hours of a 2 week testing period, using a StepWatch activity monitor system (Cyma, Inc., Mountlake Terrace, WA; Thompson et al., 2007). Despite a walk-and-work station increasing energy expenditure and feasibly increasing steps over a 2 week period, researchers have yet to conduct an intervention study using such a work station to evaluate changes in health outcomes over a longer period of time.

Because the use of a walk-and-work station requires costly alterations to an office setting, other devices manipulating sedentary time may be more reasonable. Carr et al. (2011) measured the feasibility of using a portable pedal exercise machine among sedentary workers (N = 18, female = 16) to reduce sedentary time over a 4 week period. Of the 20 available working days with the pedal exercise machine, workers used it an average of 12.2 (SD = 6.6) days and reduced sedentary time by 23.4 (SD = 20.4) minutes each day they pedaled. A feasibility questionnaire showed participants thought the portable pedal exercise machine was practical and helped them to reduce sedentary time (Carr et al., 2011). Using indirect calorimetry, another study showed the use of an office-place stepping device that can be easily stored under a desk, can be used to increase energy expenditure compared to sitting in an office chair by 289 ± 102 kcal/h (McAlpine et al., 2007). Among the 19 participants, obese individuals increased energy expenditure 335 ± 99 kcal/h compared to sitting, while lean individuals expended 235 ± 80 kcal/h more than sitting (McAlpine et al., 2007). The authors predicted an office-place stepping device could lead to a weight loss of 20 kg/year if used for 2 hours per day, if other components of energy balance remained constant (McAlpine et al., 2007).

Perhaps more accessible and less expensive than a portable mechanical exercise device is an exercise stability ball. First though, it is important to understand the advantages and disadvantages of using a stability ball instead of a chair. In regard to energy expenditure, some studies have shown sitting on a stability ball increases energy expenditure approximately 4 kcal/h or more compared to chair sitting (Beers et al., 2008; Faries et al., 2011; Haller, Roberts, & Freedson, 2006) and if practiced over time for several hours a day, it may lead to meaningful increases of energy expenditure (Haller et al., 2006). Besides potentially increasing energy expenditure, sitting on a stability ball also advantageously increases trunk motion and lumbar variation (Kingma & van Dieen, 2009). However, despite these advantages, the act of prolonged sitting on a stability ball is not recommended (McGill et al., 2006; Gregory et al., 2006). Although some claim sitting on a stability ball over a chair can improve spinal posture while sitting and decrease spinal loads, evidence suggests there is no difference in magnitudes between these modes of sitting (McGill et al., 2006). Disadvantages of prolonged sitting on a stability ball include spinal shrinkage (Kingma & van Dieen, 2009), decreased pelvic tilt (Gregory et al., 2006), and increased discomfort (Gregory et al., 2006; McGill, et al., 2006). It is suggested that these disadvantages outweigh the advantages (Kingma & van Dieen, 2009).

Beers et al. (2008) determined no difference in energy expenditure when performing clerical work either sitting on a stability ball or standing at a desk, with both of these activities having greater energy expenditure than performing clerical work while sitting on an office chair. This supports the idea that a clerical worker may simply stand to do office work in order to increase energy expenditure to a level equivalent to sitting on a stability ball. In addition, Levine et al., (2000) compared energy expenditure from fidgeting like activities (i.e., very low workloads) while sitting to be approximately 50% above resting values and standing to be almost 100% above resting values. While these studies suggest standing office work elicits greater energy expenditure than sitting office work, a separate study found no difference between chair sitting, sitting on a stability ball, or standing (Speck & Schmitz, 2009). Speck (2011) explained that standing at work instead of sitting for an 8 hour period hypothetically increases daily energy expenditure by 384 kcals for a 60 kg person, according to the Compendium of Physical Activities (Ainsworth et al., 2011), but using indirect calorimetry, energy expenditure did not differentiate between chair sitting, sitting on a stability ball, or standing (Speck & Schmitz, 2009). This results in the question of whether or not a standing intervention would actually increase energy expenditure.

Furthermore, to implement an intervention such as standing, it is important to be aware of ergonomic recommendations for physical activity at work to avoid musculoskeletal disorders (Commissaris, Schoenmaker, & de Korte, 2006). Although typically occurring in the neck and shoulder region, the main risk of musculoskeletal disorders is due to prolonged, low-intensity, static loading on muscles (Sjogaard & Jensen, 2006). It is recommended that during an 8-hour work day, continuous standing should not exceed 1 hour, continuous sitting not to exceed 2 hours, and total standing time not to exceed 4 hours (Commissaris et al., 2006).

Overall, there are relatively few studies that have intervened to reduce sedentary time (sitting time) in the workplace (Chau et al., 2010). Among these studies that have focused on the effect of workplace interventions to reduce sedentary time, there remains no ideal solution in the literature how to decrease sedentary time. While the walk-in-work station appears to elicit the greatest energy expenditure, it may not be feasible in every work place. Portable pedal and step machines provide adequate stimulation for health benefits if used enough, but are likely only to be used every other day and for short periods of time. Also, it is possible that instead of only reducing sedentary time, the participant may also be engaging in moderate physical activity when using these devices, possibly confounding the ability to see the effects of reduced sedentary time. A stability ball, although popular, used for long periods of time to reduce sedentary time has more disadvantages than advantages. A standing intervention alone may not elicit changes in energy expenditure, but with suggested activities and goals to increase light activity and decrease sedentary time, may be effective, if done in a way to influence more than 48 minutes a day. Specifically regarding sedentary time in the workplace, Chau et al. (2010) concluded that more evidence is needed to determine if workplace interventions reduce sedentary time.

Conclusions

There is substantial evidence that sedentary time is associated with negative health consequences (Bankosk et al., 2011; Ford et al., 2005; Healy, Wijndaele, et al., 2008; Healy, Matthews, et al., 2011; Katzmarzyk et al., 2009). When conducting and reporting research on sedentary behavior, it is important for researchers to identify both the instrument selected to measure sedentary behavior and the component of sedentary behavior being assessed. This will help further detect metabolic pathways of disease related to sedentary behavior and relate findings to specific measures and outcomes. In order to evaluate changes in sedentary behavior, the instrument used must be sensitive enough to capture changes between sedentary behavior and light activity. The AP appears to be the most practical instrument to measure time in sedentary posture and the SWA has potential to be the most practical tool to measure energy expenditure if validated during sedentary behavior and light activity.

For an intervention reducing sedentary time to be effective, it is probable the intervention should reduce sedentary time a minimum of two to three hours a day (Healy et al., 2007; Healy, Matthews, et al., 2011; Hu et al., 2003; Katzmarzyk et al., 2009; Sugiyama et al., 2008). It appears feasible to reduce short-term (i.e., $\leq$ 4 weeks) sedentary time through different mediums, but more research should be conducted to determine the best medium and time to reduce sedentary behavior. In addition, to the authors' knowledge, the feasibility of long-term reductions of sedentary behavior has not been determined. Health variables that have shown consistent association with sedentary time now need to be analyzed through intervention studies reducing objectively-measured, sedentary time. These variables include waist circumference (Healy, Wijndaele, et al., 2008; Healy, Matthews, et al., 2011), triglycerides (Healy, Matthews, et al., 2011; Healy, Wijndaele, et al., 2008), insulin (Healy, Matthews, et al., 2011), 2-h plasma glucose (Healy et al., 2007), HDL-cholesterol (Healy, Matthews, et al., 2011), C-reactive protein (Healy, Matthews, et al., 2011), and HOMA-%S and HOMA-%B (Healy, Matthews, et al., 2011). To our knowledge, neither acute nor chronic effects of reducing sedentary time on any of these variables have been studied. With the availability of objective measures of sedentary behavior and growing knowledge of the dangers of sedentary behavior, innovated interventions to reduce sedentary time are justified and needed.

CHAPTER III

VALIDATION OF THE SENSEWEAR™ ARMBAND AS A MEASURE OF SEDENTARY BEHAVIOR AND LIGHT ACTIVITY

Introduction

Sedentary behavior can be identified as an absolute intensity between 1.0 and 1.5 metabolic equivalent tasks (METs; Pate, O'Neil, & Lobelo, 2008). This typically reflects lying down, sitting quietly, watching television, or riding in a vehicle for transportation (Ainsworth et al., 2011). Light activity is understood to be between 1.6 and 2.9 METs and typically reflects standing or other movement behaviors characteristically requiring little effort (Ainsworth et al., 2011; Pate et al., 2008). Categorizing these separately can help reveal the individual roles of sedentary behavior and light activity on specific health outcomes (Hamilton, Hamilton, & Zderic, 2004; Healy, Matthew, Dunstan, & Winkler, 2011; Katzmarzk, Church, Craig, & Bouchard, 2008; Owen, Healy, Matthews, & Dunstan, 2010; Trembaly, Colley, Saunders, Healy, & Owen, 2010).

Energy expenditure due to sedentary behavior and light activity can be described as non-exercise activity thermogenesis (NEAT; Levine, Eberhardt, & Jensen, 1999). When sedentary time is replaced with standing or light activity, NEAT increases (Hamilton, Hamilton, & Zderic, 2007; Levine et al., 2005; Levine, Vander Weg, Hill, & Klesges, 2006). For example, replacing 2 hours of sitting a day with non-exercise activities of daily living can increase NEAT by approximately 350 kcals per day (Levine et al., 2005). An increase in NEAT may also limit fat gain due to over eating (Levine et al., 1999). Hamilton et al. (2007) explained that the majority of hours in a day for most people are spent in a state of low energy expenditure (e.g. low NEAT), largely due to too much sitting. Low energy expenditure and sitting time have been linked to health problems such as metabolic syndrome (Bertrais et al., 2005; Dunstan et al., 2005; Ford, Kohl, Mokdad, & Ajani, 2005; Gao, Nelson, & Tucker, 2007; Healy et al., 2008), type 2 diabetes (Hu, Li, Colditz, Willett, & Manson, 2003), and obesity (Sugiyama, Healy, Dunstan, Salmon, & Owen, 2008).

Because low energy expenditure helps define sedentary behavior and is seen as a pathway for health consequences, it is imperative to have practical and valid instruments to reliably estimate energy expenditure of sedentary and light activities. Instruments that can be used to objectively assess sedentary and light activity are the activPAL (PAL Technologies Ltd., Glasgow, UK), ActiGraph (ActiGraph LLC, Pensacola, FL), and the Intelligent Device for Energy Expenditure and Physical Activity (IDEEA). However, the activPAL has been shown to lack accuracy in measuring energy expenditure (Harrington, Welk, & Donnelly, 2011), the ActiGraph uses only correlated activity counts to estimate energy expenditure (Freedson, Melanson, & Sirard, 1998; Kozey-Keadle, Libertine, Lyden, Staudenmayer, & Freedson, 2011), and the IDEEA requires specific placement of multiple wires taped in place, making it less practical. It has been recommended that, in addition to these tools, other instruments may improve the measurement of sedentary behavior (Pate et al., 2008).

The Sensewear armband (SWA; Body Media, Pettsburgh, PA, USA) is worn on the upper left arm and has been validated to measure energy expenditure at rest (Fruin & Rankin, 2004; Malavolti et al., 2006; Papazoglou et al., 2006; Welk, McClain, Eisenmann, & Wickell, 2007) and during exercise (Fruin & Rankin, 2004; Jakicic et al., 2004; King, Torres, Potter, Brooks, & Coleman, 2004; Papazoglou et al., 2006). Furthermore, Welk et al. (2007) used the IDEEA to validate the SWA for everyday activities in a free-living environment among college students, but noted a need for further cross validation in other populations using precise activity transition points.

Therefore, the purpose of this study was to validate the SWA monitor in assessing energy expenditure (kcal/min) during sedentary behavior and light activity in a laboratory setting among adults. This was accomplished by assessing energy expenditure for a variety of sedentary behaviors and light activities and correlating indirect calorimetry (Oxycon Mobile) and SWA measures. A second validation was conducted evaluating the SWA's accuracy in detecting differences in energy expenditure between sedentary and light activities. Finally, because objectively measured MET values from the SWA can be used to classify time spent in sedentary or light behavior, the percent of correct intensity classification was calculated by comparing SWA intensity classification with the Oxycon Mobile classification of intensity.

Methods

Participants

Participants (*N* = 22) were recruited via flyers and word of mouth from the greater Nashville area. To be eligible to participate, able bodied participants had to be between 30 and 65 years of age. Participant characteristics are displayed in Table 1.

Instrumentation

Anthropometric measurements. Body mass was measured using a digital scale (SECA Corporation, Model 770, Germany) to the nearest 0.1 kg. Height was assessed

Table 1

Demographic Characteristics of Sample

	Females (n = 11)	Males (n = 11)	Full sample (N = 22)
Age (years)	45 ± 11.8	45 ± 12.1	45 ± 11.7
Height (cm)	163.0 ± 6.7	175.5 ± 5.6	169.3 ± 8.8
Body mass (kg)	73.2 ± 15.8	84.3 ± 12.6	78.7 ± 15.0
BMI (kg/m^2)	27.4 ± 5.2	27.3 ± 3.9	27.4 ± 4.5

Note. Values represent mean ± standard deviation.

using a stadiometer (SECA Corporation Model 222, Germany) to the nearest 0.1 cm. Participants removed shoes for both body mass and height measurements. For descriptive purposes, body mass and height were used to calculate body mass index (BMI; kg/m^2).

Oxycon Mobile (Oxycon). The Oxycon™ is a portable open-circuit indirect calorimetry system and allows participants normal range movements during breath by breath assessment of energy expenditure by only wearing a light weight mask and small pack. Before each test, the Oxycon was calibrated using an automatic gas analyzer and automatic volume calibration unit. This measurement acted as the criterion value for energy expenditure. Energy expenditure was measured in 1-minute epochs.

SWA (Model MF-SW). After programming the SWA using sex, age, height, and body mass, the SWA was placed on the participants' upper left arm (over the triceps muscle), halfway between the acromion and olecranon processes. Several sensors on the device (i.e., accelerometer, skin temperature sensor, galvanic skin response, and heat flux) gathered information to derive energy expenditure (Andre et al., 2006). Algorithms using the 2.2r3 with the 7.0 software were used. Energy expenditure was measured in 1-minute epochs.

Resting metabolic rate (RMR). To standardization energy expenditure measurements RMR procedures were followed. Participants were asked to avoid smoking and fast for 12 hours (only drinking water) prior to being tested. In addition, they were asked to refrain from participating in structured physical activity for 24 hours before testing, keep movement on the morning of the test day to a minimum, and arrive to the lab within 2 hours of waking on test day. After putting on both the SWA and

Oxycon, participants were isolated in a room ranging between 21 and 24 degrees Celsius and rested quietly

awake in a supine position. Participants remained in this state approximately 25-30 minutes, depending on the variability of the respiratory quotient. This measurement was completed after a minimum of 15 minutes of steady state, defined by less than 5% variability in the minute by minute respiratory quotient (Malavolti et al., 2007; Papazoglou et al., 2006).

Sedentary and light activity measurements. Six sedentary to light activities were randomly conducted: (1) supine condition, (2) sitting on a typical office chair with hands resting on thighs without body movement or talking (sitting NM), (3) standing with hands resting to the side without body movement or talking (standing NM), (4) sitting on a typical office chair while performing light office work (sitting OW), (5) standing while performing light office work (standing OW), and (6) slow walking at 1.0 mph, simulating a typical office treadmill speed or very light office walk. Light office work was scripted (see Appendix A) and included normal office movements (e.g. typing, filing papers, emailing, etc…).

Procedures

Preparation. Approximately a week before participating in the study, participants completed the informed consent (see Appendix B) approved by the University Institutional Review Board (see Appendix C) and were given specific preparation instructions for RMR testing.

Test day. Participants arrived at the lab on the morning of their test day between 7:00 and 10:00 AM. After calibrating the Oxycon, anthropometric measurements were taken and the SWA and Oxycon were programmed for each participant. The participant received specific instruction of how each device would be worn and reminded what measurements would take place. After placing each testing device on the participant, a 10 minute acclimatization period was performed by having the participant lie comfortably in a supine position. Following this acclimatization period, participants remained in the same position and RMR procedures were completed.

Following the RMR measurement, sedentary and light activity measurements were randomly ordered and each administered for 5 minutes. Between measurements, participants returned to a supine condition until their respiratory quotient returned within 5% of baseline.

Statistical Analysis

Data analysis was conducted using International Business Machines Corporation Statistical Packages for the Social Sciences (version 19.0) software. Descriptive statistics for participants were expressed as means $\pm$ standard deviations and statistical significance was defined with an alpha level of $p < .05$. Using the average caloric expenditure per minute from minutes four and five of each activity, Pearson correlation and intraclass correlation coefficients (ICC) with confidence intervals were computed between the Oxycon (kcal/min) and SWA (kcal/min). Bland-Altman plots were employed to visually assess the agreement between measurements of the SWA and the Oxycon (Bland & Altman, 1986). Two-way repeated measures ANOVA determined energy expenditure differences between measurement methods and within each activity followed by simple effect tests with adjusted alpha levels. Finally, percentages of the

SWA correctly classifying sedentary, light, or moderate activity were calculated based on the Oxycon classification.

Results

All participants were nonsmokers and ranged from 30 to 64 years of age. Participants had a range of BMI valued between 21.6 and 38.1 (kg/m^2). Using BMI weight classification cut points, 46% of participants were normal weight, 32% were overweight, and 23% were obese. See Table 1 for demographic characteristics.

Using the average energy expenditure across all conditions, the overall Pearson correlation between the Oxycon and SWA was significant, $r(20) = .90$, $p < .001$. Using the average energy expenditure across all conditions, the overall ICC (consistency type mixed model) was significant, ICC = .90, 95% CI [.699, .966]. See Table 2 for Pearson correlations and ICC results between the Oxycon and SWA for each activity. See Figure 1 for a Bland-Altmon plot of overall agreement between energy expenditure from the Oxycon and SWA.

Descriptive statistics of energy expenditure for each activity from both measurement methods are included in Table 3. Two-way repeated measures ANOVA (method [2] x activity [6]) identified a significant interaction, *Wilks's* $F(5, 17) = 19.57$, $p < .001$, $\eta_p^2 = .85$. An adjusted alpha level of .025 was applied for the simple effect tests by method. The simple effects tests for both the Oxycon, *Wilks's* $F(5, 17) = 62.04$, $p < .001$, $\eta_p^2 = .95$ and SWA, *Wilk's* $F(5, 17) = 59.66$, $p < .001$, $\eta_p^2 = .95$ were significant. Using pairwise comparisons, the Oxycon detected significant differences in energy expenditure between all activity levels except supine and sitting NM, and supine and

Table 2

Pearson and Intra Class Coefficients between Oxycon and SWA by Activity

					95% CI	
Activity	Pearson	*p*	ICC	*p*	Low	High
Supine	.532	.011	.532	.005	.008	.826
Sitting NM	.751	< .001	.749	< .001	.368	.914
Standing NM	.697	< .001	.683	< .001	.245	.889
Sitting OW	.834	< .001	.807	< .001	.488	.936
Standing OW	.673	.001	.600	.001	.109	.856
Walking (1 mph)	.513	.015	.492	.009	-.045	.809
All Activities	.897	< .001	.895	< .001	.699	.966

Note. $p < .05$; NM = no movement; OW = office work; SWA = Sensewear armband.

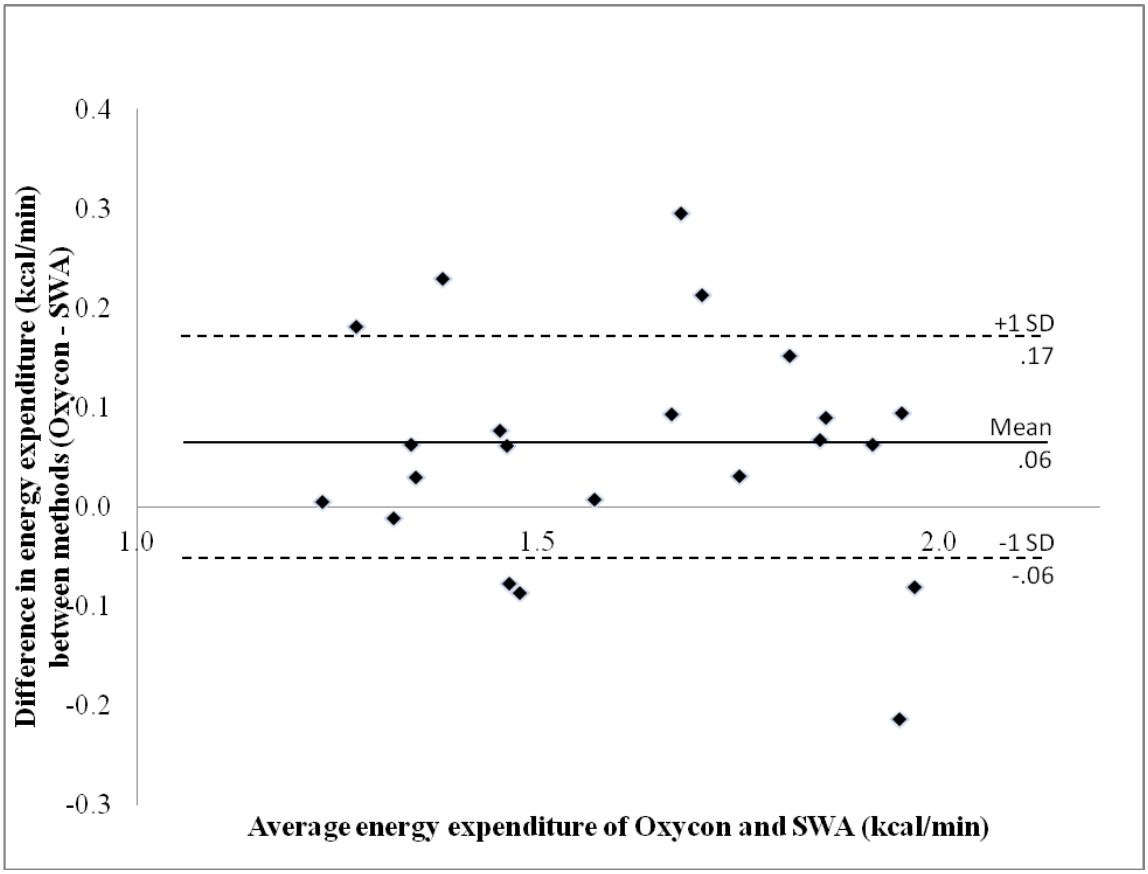

Figure 1. Bland-Altmon plot of mean differences between measurement methods. *Note.* SWA = Sensewear armband.

Table 3

Descriptive Statistics for Energy Expenditure (kcal/min)

Activity	Oxycon		SWA	
	M	*SD*	*M*	*SD*
Supine	1.19	.19	1.23	.19
Sitting NM	1.15	.21	1.19	.19
Standing NM	1.29	.23	1.16	.19
Sitting OW	1.59	.26	1.28	.20
Standing OW	1.71	.28	1.40	.46
Walking (1 mph)	2.92	.60	3.23	.80
Average of All Activities	1.64	.25	1.58	.26

Note. NM = no movement; OW = office work; SWA = Sensewear armband.

standing NM (See Table 4). The SWA detected significant differences between energy expenditure for all activities except supine and sitting OW, supine and standing OW, sitting NM and sitting OW, sitting NM and standing OW, standing NM and standing OW, and sitting OW and standing OW (See Table 4).

An alpha level of .01 was used for simple effect tests by activity. Paired t-tests revealed no significant difference in caloric expenditure between measurement methods using the Oxycon and the SWA while in a supine position, $t(21) = -1.18$, $p = .251$, $\eta_p^2 = .06$, sitting NM, $t(21) = -1.24$, $p = .230$, $\eta_p^2 = .07$, and while walking at 1 mph, $t(21) = -2.06$, $p = .052$, $\eta_p^2 = .17$. Significant differences in energy expenditure between the Oxycon and SWA existed while standing NM, $t(21) = 3.54$, $p = .002$, $\eta_p^2 = .37$, sitting OW, $t(21) = 10.12$, $p < .001$, $\eta_p^2 = .83$, and standing OW, $t(21) = 4.25$, $p < .001$, $\eta_p^2 = .46$, see Figure 2, with the SWA having a significantly lower caloric expenditure (kcal/min).

Overall, compared to MET values derived from the Oxycon, the SWA correctly classified an average of 88.6% of sedentary, light, or moderate activities. The SWA correctly classified activity intensity 95.5% (supine position), 100% (sitting NM), 95.5% (standing NM), 86.4% (sitting OW), 68.2% (standing OW), and 86.4% (walking 1 mph) of the time.

Discussion

The purpose of this study was to validate the SWA during sedentary and light activities. There was a strong Pearson correlation and very strong ICC for energy expenditure (kcal/min) measured by the SWA and energy expenditure measured by the

Table 4

Pairwise Comparisons of Energy Expenditure (kcal/min)

	Oxycon			SWA		
Comparison	*M* Diff.	*t*	*p*	*M* Diff.	*t*	*p*
Supine - Sit NM	0.04	1.24	.230	0.05	4.31	< .001
Supine - Stand NM	-0.10	-3.42	.003	0.07	5.68	< .001
Supine - Sit OW	-0.41	-8.24	< .001	-0.05	-1.63	.117
Supine - Stand OW	-0.52	-11.04	< .001	-0.17	-1.70	.103
Supine - Walk	-1.73	-14.76	< .001	-2.00	-12.42	< .001
Sit NM - Stand NM	-0.14	-4.92	< .001	0.03	4.43	< .001
Sit NM - Sit OW	-0.44	-11.05	< .001	-0.10	-3.31	.003
Sit NM - Stand OW	-0.56	-13.05	< .001	-0.21	-2.19	.040
Sit NM - Walk	-1.77	-16.66	< .001	-2.04	-13.10	< .001
Stand NM - Sit OW	-0.31	-7.39	< .001	-0.12	-4.60	< .001
Stand NM - Stand OW	-0.42	-9.84	< .001	-0.24	-2.52	.020
Stand NM -Walk	-1.63	-15.00	< .001	-2.07	-13.35	< .001
Sit OW - Stand OW	-0.11	-3.85	.001	-0.12	-1.66	.112

Table 4

Pairwise Comparison of Energy of Energy Expenditure Cont'd.

	Oxycon			SWA		
Comparison	*M* Diff.	*t*	*p*	*M* Diff.	*t*	*p*
Sit OW - Walk	-1.32	-12.25	< .001	-1.95	-12.66	< .001
Stand OW - Walk	-1.21	-11.70	< .001	-1.83	-10.86	< .001

Note. Significance is based on familywise alpha < .05 (Sidak adjustment < .002); *M* Diff. = mean difference; NM = no movement; OW = office work; SWA = Sensewear armband.

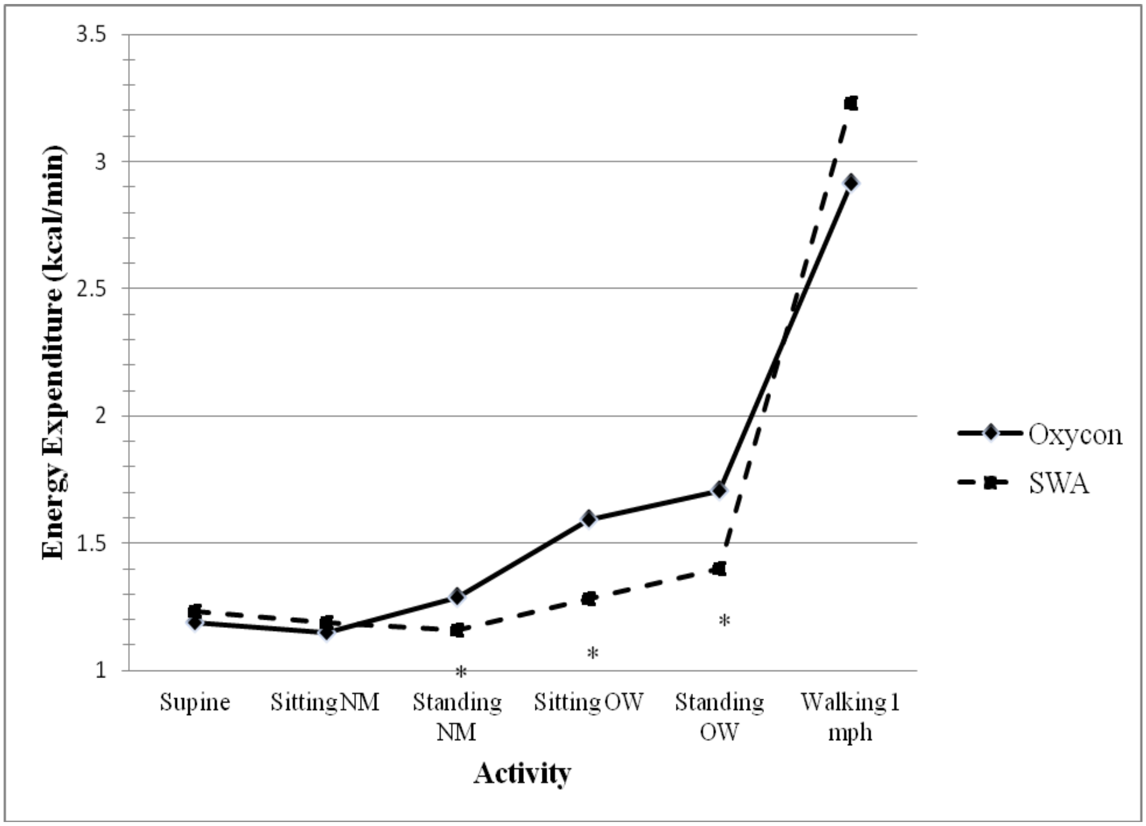

Figure 2. Energy expenditure comparison between the Oxycon and SWA by activity.

Note: * $p < .01$, between Oxycon and SWA; NM = no movement; OW = office work; SWA = Sensewear armband.

Oxycon (indirect calorimetry) during a variety of sedentary and light activities in a laboratory setting among adults. The SWA was able to detect differences in energy expenditure between some sedentary and light activities. However, the SWA was not sensitive enough to detect differences in energy expenditure while performing office work sitting versus standing. Specifically, the SWA under-predicted energy expenditure while standing still and while performing office work (sitting and standing). Overall, the MET values derived from the SWA correctly categorized sedentary, light, and moderate activities nearly 90% of the time. However, the SWA was less effective during standing office work, misclassifying this light activity as a sedentary activity.

To our knowledge, this study is the first to validate the SWA specifically for sedentary and light activities in a laboratory setting against indirect calorimetry. The majority of the SWA validation data have included different modes and intensities of moderate to vigorous physical activity (Fruin & Rankin, 2004; Jakicic et al., 2004; King et al., 2004; Papazoglou et al., 2006). The studies that have included some sedentary or light activities reported similar results as the current study (Berntsen et al., 2011; Smith, Lanningham-Foster, Welk, & Campbell, 2012).

The overall ICC reported in this study (.90) between the SWA and indirect calorimetry was similar to ICCs of .85 from Berntsen et al. (2011) and .87 from Smith et al. (2012). These researchers evaluated energy expenditure of sedentary and light activities among pregnant women during daily living activities while using the SWA Pro_2 (Berntsen et al., 2011) and the SWA Mini (Smith et al., 2012). Furthermore, evidence from the current study identifying validity of the SWA during multiple sedentary and light activities supports other studies that have included at least one sedentary or light condition. For example, the correlation of all sedentary and light activities found in the current study (r = .90) between the SWA and indirect calorimetry are also similar to results of resting measures from Fruin and Rankin (2004), Malavolti et al. (2006), and Papazoglou et al. (2006) r = .76, r = .86, r = .88, respectively.

Despite identifying differences in energy expenditure across some sedentary and light activities, the SWA did not detect significant energy expenditure changes while doing office work due to postural changes from sitting to standing. However, the actual difference in energy expenditure between sitting OW and standing OW was similar between measurement methods. A larger standard deviation while standing OW in the SWA measurement indicated greater variability. Perhaps this greater variability was due to variations in the amount of arm movement by the participants.

The current study showed the SWA to underestimate energy expenditure for standing NM and standing or sitting OW. This was similar to Berntsen et al. (2011) who showed the SWA Pro_2 underestimated energy expenditure by 9% during free-living conditions, but different from Smith et al. (2012) who showed the SWA Mini to overestimate energy expenditure. This may be partly explained by the type of sedentary or light activity being performed in each study. For example, the activities that underestimated energy expenditure in the current study and the study by Bernsten et al. (2011) involved less movement of the upper arm, while the activities that overestimated energy expenditure in the study by Smith et al. (2012) required greater arm movement (i.e., folding laundry, sweeping).

An over-estimation of energy expenditure for the SWA is also more prevalent in moderate or vigorous activities involving more upper-body or arm motions (Jakicic et al., 2004). The current study included some movement of the upper arm during office work through use of a computer mouse, writing, or filing papers, but performing office work naturally requires more upper arm movement to the side of the dominant hand. If the armband, being placed on the left arm, was not on the dominant hand side, it likely remained relatively motionless when using a computer mouse or writing. While algorithms exist to compensate for dominant hand usage, it is unknown if these algorithms are validated for sedentary or light activities. The results of this study suggest the need for algorithms involving the use of the dominant and non-dominant hand during sedentary and light activities involving arm movements. This is important because an underestimation in caloric expenditure may also lead to differences in intensity classification when using the SWA to monitor sedentary behavior or physical activity intensities.

Designated MET value cut points can be used to determine the amount of time spent in sedentary behavior or physical activity intensity levels. The results of this study indicate the SWA correctly classified sedentary behavior and light activity the majority of the time when compared to classifications made through indirect calorimetry. These results are similar to Unick et al. (2012) who classified intensity by MET value and found no difference in sedentary and light activity time measured between the SWA Pro_2 (sedentary = 602.3 ± 128.6 minutes; light = 120.6 ± 65.7 minutes) and the Stayhealthy RT3 Triaxial accelerometer (sedentary = 582.9 ± 94.3 minutes; light = 131.9 ± 60.0 mintues). Overall, the SWA accurately classified time spent in sedentary and light activities in the present study, but was least effective in classifying standing OW by sometimes classifying it as sedentary when it was actually light activity.

Despite controlling for differences in office work intensity by having all participants follow a set script, energy expenditure during office tasks varied by participant. Though a MET value of 1.5 is considered sedentary (Pate et al., 2008) and used for occupational sitting tasks with light effort (Ainsworth et al., 2011), some of our participants measured above 1.5 METs with the Oxycon during office tasks and were classified as performing light intensity activities. This is important to acknowledge because the SWA can misclassify sedentary and light intensities. This result of misclassifying light intensity as sedentary intensity while performing standing OW, was due to an underestimation of energy expenditure. Acknowledgement of this misclassification should be noted in future research using the SWA for monitoring sedentary and light activity.

While the current study included both sedentary and light activities, results are limited to only the conditions tested. These conditions were specific to office work. Also, a smaller sample size limited the ability to analyze sex differences that may exist for energy expenditure. Future research may identify, evaluate, and validate other sedentary or light activities by occupation.

In conclusion, estimated energy expenditure from the SWA was strongly correlated to indirect calorimetry during sedentary and light activities. The SWA underestimated energy expenditure when standing and when performing office work (standing and sitting). This underestimation may lead to overestimating total time spent in sedentary behavior when monitoring sedentary behavior. However, it correctly classified sedentary and light activity based on MET value cut points nearly 90% of the time. Overall, the SWA is a valid monitor of sedentary behavior and light activity. As more valid and reliable measurement tools are used to objectively quantify sedentary behavior and light activity (Hart, Ainsworth, & Tudor-Locke, 2011), programs developed to reduce sedentary behavior can better be evaluated. As measurement tools become more sensitive to changes in sedentary behavior, greater emphasis can be placed on decreasing sedentary time to improve health variables.

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Appendix for Study I

Appendix A

Light Office Work Script

Perform the following office tasks:

1) Do the following for 1 minute and 40 seconds:
    a. Using the computer, create a new word document and "save as" your last name on the desk top.
    b. Using the book on your right, turn to page 40.
    c. Beginning with page 40, type as much as you can, replicating the page. Save what you have been working on at the end of the time.
2) Do the following for 1 minute and 40 seconds:
    a. Using the filing system on your left, find the folder titled "Leonard."
    b. Once you have found the file, look for the papers titled "Leadership Assessment Report"
    c. Thinking of someone you know, fill out the "Leadership Assessment Report." At the end of the time place the report back in the folder and re-file in the correct spot (alphabetical order).
3) Do the following for 1 minute and 40 seconds:
    a. Log onto your email account
    b. Create a new email to send to jdr5f@mtmail.mtsu.edu
    c. Title the email (use your imagination)
    d. Attach the document you were working on earlier saved as your last name
    e. For the content of the email you can write anything you want. Just continue to work on it and send the email at the end of the time.

Appendix B

Informed Consent

MTSU
IRB Approved
Date: 5/14/2012

Principal Investigator: Joel Reece
Study Title: VALIDATION OF THE SENSEWEAR™ ARMBAND AS A MEASURE OF SEDENTARY AND LIGHT ACTIVITY ENERGY EXPENDITURE
Institution: Middle Tennessee State University

Name of participant: ____ Age: __________

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**
   You are being asked to participate in a research study because there is a need to validate objective measurement tools of sedentary behavior. Your participation will help determine if the objective measurement tool of interest is comparable to the gold standard measurement of energy expenditure.

2. **Description of procedures to be followed and approximate duration of the study:**
   Prior to arriving to the lab for your scheduled participation you should **(1)** abstain from structured physical activity for 24 hours, **(2)** Fast for 12 hours, abstaining from smoking, food, and drink (water is ok), **(3)** Perform minimal movement the morning of your appointment, and **(4)** Arrive to your appointment within 2 hours of waking.
   Once you arrive to the lab, your height, weight, sex, and age will be recorded. You will be asked to wear two measurement devices, one on your left upper arm and the other, a rubberized mask similar to an oxygen mask, comfortably placed around your mouth and nose. The mask is worn to help measure the exact amount of oxygen being breathed in and out. You will then be asked to lie awake comfortably on your back for approximately 30-45 minutes while your baseline is measured. Following this, you will randomly perform the following activities for 5 minutes each: (1) supine condition, (2) sitting on a typical office chair with hands resting on thighs without body movement or talking, (3) standing with hands resting to the side without body movement or talking, (4) sitting on a typical office chair while performing light office work, (5) standing while performing light office work, and (6) slow walking at 1.0 mph. Between each activitie you will resume lying on your back until you return within 5% of baseline measurements. Your scheduled participation will last approximately 2 hours.

3. **Expected costs:**
   There is no cost to you for you participation.

4. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:**
   While there are no apparent risks for participating, you may experience some discomfort or inconveniences from fasting before arriving to the lab or wearing the measurement devices.

5. **Compensation in case of study-related injury:**
   MTSU will not provide compensation in the case of study related injury.

Middle Tennessee State University Institutional Review Board
Informed Consent Document for Research

6. **Anticipated benefits from this study:**
   a) The potential benefits to science and humankind that may result from this study is the ability to objectively measure sedentary behavior leading to future research focused on health consequences of sedentary behavior.
   b) The potential benefits to you from this study are learning about sedentary behaviors and obtaining your individual resting metabolic rate.

7. **Alternative treatments available:**
   There are no alternative treatments available.

8. **Compensation for participation:**
   There is no monetary compensation for participating in this study.

9. **Circumstances under which the Principal Investigator may withdraw you from study participation:**
   If conditions prior to arriving to the lab are not met, the principal investigator may withdraw you from participation.

10. **What happens if you choose to withdraw from study participation:**
    There are no consequences for withdrawing from the study.

11. **Contact Information.** If you should have any questions about this research study or possible injury, please feel free to contact Joel Reece at 801-234-0973 or my Faculty Advisor, Dr. Caputo at 615-898-5547.

12. **Confidentiality.** All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.

13. **STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY**
    I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

________________ ________________________________
Date Signature of patient/volunteer

Consent obtained by:

________________ ________________________________
Date Signature

____
Printed Name and Title

Appendix C

IRB Letter of Approval

MIDDLE TENNESSEE STATE UNIVERSITY

May 14, 2012

Joel Reece, Jennifer Caputo, Vaughn Barry, Dana Fuller
Department of Health and Human Performance

Protocol Title: "VALIDATION OF THE SENSEWEAR™ ARMBAND AS A MEASURE OF SEDENTARY AND LIGHT ACTIVITY ENERGY EXPENDITUR"

Protocol Number: **12-315**

Dear Investigator(s),

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under the 45 CFR 46.110 Category 7.

Approval is granted for one (1) year from the date of this letter for 40 participants.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. **If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance (c/o Emily Born, Box 134) before they begin to work on the project.** Any change to the protocol must be submitted to the IRB before implementing this change.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918.

You will need to submit an end-of-project form to the Office of Compliance upon completion of your research located on the IRB website. Complete research means that you have finished collecting and analyzing data. **Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date.** Please allow time for review and requested revisions. Your study expires **May 14, 2013**.

Also, all research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Emily Born

Emily Born
Research Compliance Officer
Middle Tennessee State University

CHAPTER IV

THE FEASIBILITY OF BEHAVIORAL STRATEGIES ON REDUCING SEDENTARY TIME AND INCREASING ENERGY EXPENDITURE IN THE WORKPLACE

Introduction

Both sedentary behavior (≤ 1.5 metabolic equivalent tasks; MET) and light activity (1.6 - 2.9 MET) describe ordinary actions performed in the workplace. Sedentary behavior in the workplace may be reflected by sitting at a desk, reading, writing, typing, or carrying out other tasks while sitting (Ainsworth et al., 2011; Pate, O'Neill, & Lobelo, 2008). Light activity in the workplace may be reflected by tasks involving standing, walking, or active work stations.

Adults spend approximately 95% of their day in sedentary behavior and light activity (Gardiner, Eakin, Healy, & Owen, 2011; Kozey-Keadle, Libertine, Staudenmayer, & Freedson, 2012), with nearly 8 hours of this time being sedentary (Matthews et al., 2008). Harmful effects associated with sedentary behavior include increased risk of mortality (Dunstan et al., 2010), increased obesity (Sugiyama, Healy, Dunstan, Salmon, & Owen, 2008), poor cardio-metabolic biomarkers (Healy, Matthews, Dunstan, Winkler, & Owen, 2011), elevated blood glucose levels (Healy et al., 2007), increased risk of type II diabetes (Hu, Li, Colditz, Willett, & Manson, 2003), and increased risk of metabolic syndrome (Bertrais et al., 2005; Dunstan et al., 2005; Ford, Kohl, Mokdad, & Ajani, 2005; Gao, Nelson, & Tucker, 2007; Healy et al., 2008). With growing evidence of sedentary behavior's harmful effects on health (Levine, Vander Weg, Hill, & Klesges, 2006; Owen, Healy, Matthews, & Dunstan, 2010; Pate et al., 2008), it is important to find effective ways to reduce sedentary behavior.

Over the past 50 years, the prevalence of sedentary or light activity occupations has increased from approximately 50% to 80% of all occupations (Church et al., 2011). The trend of moderately active occupations decreasing and sedentary and light occupations increasing has resulted in an estimated decrease of energy expenditure in the workplace of 142 calories per day (Church et al., 2011). With the rising number of sedentary workers, it is important to determine strategies to decrease sedentary time and increase energy expenditure in the workplace.

In an attempt to reduce sedentary behavior and increase physical activity among office workers or in the workplace, researchers have begun to evaluate the use of counseling and fitness testing (Aittasalo, Miilunpalo, & Suni, 2004; Osteras & Hammer, 2006), web based interventions (Marshall, Leslie, Bauman, Marcus, & Owen, 2003; Plotnikoff, McCargar, Wilson, & Loucaides, 2005), face-to-face and phone-based coaching (Opdenacker & Boen, 2008), portable pedal exercise machines (Carr, Walaska, & Marcus, 2011), standing interventions (Gilson, Suppini, Ryde, Brown, & Brown, 2012; Levine, Schleusner, & Jensen, 2000; Speck, 2011; Speck & Schmitz, 2009), "walk-and-work" stations (Levine & Miller, 2007; Thompson, Foster, Eide, & Levine, 2007), portable stepping devices (McAlpine, Manohar, McCrady, Hensrud, & Levine 2007), and stability balls (Beers, Roemmich, Epstein, & Horvath, 2008; Faries, Bartholomew, & McCalister, 2011; Gregory, Dunk, & Callaghan, 2006; Kingma & van Dieen, 2009; McGill, Kavcic, & Harvey, 2006). However, these studies have generally used only self-report measures of sedentary behavior (i.e., sitting time) which are subjective and may not be sensitive to short duration (< 5 minutes) changes of sedentary behavior (Hart, Ainsworth, & Tudor-Locke, 2011). Overall, Chau et al. (2010) concluded there was a "dearth" of research evaluating the effectiveness of interventions to reduce sitting time in the workplace and suggested the importance of using objective measures to identify changes in sedentary time.

Few researchers have attempted to objectively measure reductions in sedentary time, perhaps none of which that have evaluated reductions of sedentary time in the workplace (Gardiner et al., 2011; Kozey-Keadle et al., 2012; Otten, Jones, Littenberg, & Harvey-Berino, 2009). These approaches to reduce sedentary time throughout the entire day (~15 – 16 hours) included educational material with suggestions to increase light activity and break up sedentary time in the workplace and outside of the workplace (Kozey-Keadle et al., 2012), face-to-face goal setting and consultation (Gardiner et al., 2011), and reducing television viewing by 50% (Otten et al., 2009). In general, these behavioral strategies decreased sedentary time by approximately 3% to 5% (~48 minutes) during waking hours (Gardiner et al., 2011; Kozey-Keadle et al., 2012; Otten et al., 2009). While it is suggested reducing sedentary time by 48 minutes may not be sufficient to elicit health benefits (Kozey-Keadle et al., 2012), it may be possible to strengthen the effect of behavioral strategies to reduce sedentary behavior by focusing more strictly on a single sedentary determinant (e.g., sedentary workplace).

To continue the advancement of sedentary research, it is important for researchers to use objective measurements of sedentary behavior (Kozey-Keadle, Libertine, Staudenmayer, & Freedson, 2011) to identify feasible and effective strategies that reduce sedentary behavior in the workplace (Chau et al., 2010; Hamilton, Healy, Dunstan, Zderic, & Owen, 2008; Owen et al., 2010; Tremblay, Colley, jSaunderds, Healy, & Owen, 2010). Therefore, the purpose of this study was to identify the feasibility of behavioral strategies promoting less sedentary time (i.e., education, one-on-one counseling, self-monitoring), to reduce sedentary time and increase light activity using objective measurements of sedentary and light activity energy expenditures in the workplace. Replacing sedentary time with light intensity would thus increase average energy expenditure throughout occupational hours.

Methods

Participants

Participants (*N* = 34) were recruited via fliers and word of mouth from the greater Nashville area. Eligible participants included female adults from 30 to 65 years of age with a fulltime sedentary occupation, that typically sat for the majority (self-reported more than 50%) of working hours.

Instruments

Anthropometric measurements. Body mass and height were measured using a digital scale (SECA Corporation, Model 770, Germany) to the nearest 0.1 kg and a stadiometer (SECA Corporation Model 222, Germany) to the nearest 0.1 cm, respectively. Participants removed shoes for body mass and height measurements. In addition, age was recorded and body mass index (BMI: kg/m^2) was calculated.

SenseWear™ armband (SWA). The SWA (BodyMedia, Inc., Model MF-SW, Pittsburgh, PA) was worn on the upper left arm (over the triceps muscle), halfway between the acromion and olecranon processes. The SWA was programmed using each participant's sex, age, height, and body mass. Several sensors on the SWA device (i.e., accelerometer, skin temperature sensor, galvanic skin response, and heat flux) gathered information to derive energy expenditure (Andre et al., 2006). Algorithms using the 2.2r3 with the 7.0 software were used.

Sedentary and active behavior. Minute by minute estimated energy expenditure (1 minute epoch) from the SWA was used to determine sedentary behavior and different intensities of activities throughout the workday. Sedentary time was defined as the amount of time spent at or below 1.5 METs. Time in light activity was classified by MET values between 1.6 and 2.9, moderate from 3.0 to 5.9, and vigorous from 6.0 METs and above (Pate et al., 2008).

Behavioral strategies. Behavioral strategies to reduce sedentary behavior included education materials, an office evaluation, one-on-one goal setting, and self-monitoring. Behavioral strategies were introduced through a brief office visit (approximately 20 minutes) by the researcher on an individual basis. When visiting, the researcher followed the contents of a pamphlet (see Appendix A) containing the following: (1) the prevalence of sedentary behavior, health risks associated with sedentary behavior, and suggestions to reduce sedentary behavior in the workplace, (2) questions to evaluate an office setting to identify opportunities to reduce sedentary time, (3) a place to write personal goals, and (4) a section for self-monitoring of personal goals. Typically two to four personal goals were determined by the participant after receiving feedback from the office evaluation and reviewing the suggestions to reduce sedentary time contained in the pamphlet. The participant was encouraged to post the pamphlet in her office, monitor the personal goals for one week, and told the researcher would collect the goals and self-monitoring contained in the pamphlet at the end of one week.

Procedures

Baseline measurements. The study was approved by the University Institution Review Board (see Appendix B). Eligible participants were met in their office where they completed an informed consent form (see Appendix C), and anthropometric measurements were obtained. After programming the SWA (using sex, age, height, and weight) participants received instruction and demonstration on how to wear the SWA. They were instructed to wear the SWA, as many hours as possible (up to 23 hours per day; based on manual guidelines) for 10 consecutive days, except when showering/bathing or during other water activities. The first 3 days of the baseline period data were treated as reactivity data and not analyzed. Baseline data ultimately included 4 to 5 working days. Participants received a log (see Appendix D) to record the time she arrived and departed from the office each day. All participants were contacted once during the week through email and reminded to log work hours. Participants were randomly assigned to either the intervention group or control group. Directly following the baseline measurement, all participants were met for a second time in their office to receive a newly charged device and initialize the 7 day intervention/control period.

Intervention group. Included in the second office visit, participants in the intervention group received a brief one-on-one counseling session implementing behavioral strategies to reduce sedentary behavior. Each participant received a new time log and was reminded to record the time she arrived and departed from the office each day. Participants wore the device for 7 consecutive days (5 work days and a weekend).

During this time they were instructed to implement the behavioral strategies previously discussed. For the purpose of this study, only work days were analyzed for the intervention period. Participants were again contacted and reminded to log hours during the middle of the work week.

Control group. Included in the second office visit, participants in the control group received a new time log and were reminded to record the time she arrived and departed from the office each day. They were instructed to continue wearing the device for 7 consecutive days (5 work days and a weekend). For the purpose of this study, only work days were analyzed for the intervention period. No discussion of personal behavioral strategies to reduce sedentary behavior took place. Participants were again contacted and reminded to log hours during the middle of the work week.

Follow-up. Following the intervention/control period, each participant was met a third time in his or her office space. Time logs from the intervention/control period were collected and SWA instruments returned to the researcher. A copy of the personal goals and self-monitoring were obtained from participants who were in the intervention group. Participants who were in the control group received the sedentary behavior educational material and given the opportunity to receive one-on-one counseling to help reduce sedentary behavior.

Statistical Analysis

Data were analyzed using the International Business Machines Corporation Statistical Packages for the Social Sciences (version 19.0) software. Descriptive statistics were expressed as means ± standard deviations. Statistical significance was defined with an alpha level of $p < .05$. Descriptive statistics for wear time of the SWA at work were categorized from minutes into percentages of time spent in sedentary (≤ 1.5 MET), light (1.6 – 2.9 MET), moderate (3.0 – 5.9 MET), or vigorous (> 6.0 MET) activity. Multiple two-way repeated measures ANOVAs were employed to analyze changes in sedentary time and light activity time. In addition, overall average MET level and average energy expenditure (kcal/min) were analyzed separately using two-way repeated measures ANOVAs.

Results

Two of the 34 participants originally recruited were unable to complete the study. The 32 remaining participants were female office workers and included normal weight (31%), overweight (31%), and obese (38%) individuals based on BMI (see Table 1). Caucasians (72%) made up the majority of the sample, followed by African-Americans (22%), and Hispanics (6%).

Overall, participants wore the armband an average of 505.1 ± 44.1 minutes (8.4 hours) while at work and worked an average of 4.8 ± .5 days a week. Using independent samples tests, neither average wear time (i.e., work time), *control* = 496.4 ± 34.3 (mintues), *intervention* = 515.8 ± 53.4, $t(30) = -1.23$, $p = .230$, or average days worked, *control* = 4.7 ± .4, *intervention* = 4.9 ± .5, $t(30) = -1.38$, $p = .178$, differed between groups.

Percentages representing the daily amount of time at work for each intensity level were calculated (see Table 2). A two-way repeated measures ANOVA (group [2] x time [2]) identified a significant interaction for the percentage change in sedentary time from pre and post measures between groups, *Wilks'* $F(1, 30) = 5.73$, $p = .023$, $\eta_p^2 = .16$. There was a greater decrease in percentage of sedentary time for the intervention group

Table 1

Demographic Characteristics of Sample

	Control (*n* = 16)	Intervention (*n* = 16)	Full Sample (*N* = 32)
Height (cm)	162.9 ± 4.7	162.8 ± 6.2	162.8 ± 5.4
Body Mass (kg)	73.6 ± 10.1	77.7 ± 15.8	75.7 ± 13.2
BMI (kg/m^2)	27.8 ± 3.9	29.4 ± 5.7	28.6 ± 4.9
Age (years)	47.8 ± 8.9	45.1 ± 9.5	46.5 ± 9.2

Note. Values represent mean ± standard deviation; BMI = body mass index.

Table 2

Percentage of Time Spent at Different Intensities

	Control		Intervention	
	Pre	Post	Pre	Post
Sedentary	73.1 ± 13.9	75.0 ± 14.6	75.1 ± 12.2	72.0 ± 13.4*
Light	20.1 ± 10.2	19.4 ± 11.3	17.5 ± 8.3	19.8 ± 8.9**
Moderate	6.7 ± 4.9	5.6 ± 4.2	7.4 ± 4.8	8.1 ± 6.5
Vigorous	0.1 ± 0.2	0.0 ± 0.1	0.0 ± 0.1	0.1 ± 0.3
Total Work Time (min)	497.6 ± 44.4	495.1 ± 45.0	509.6 ± 64.0	522.0 ± 59.1

Note. * = significantly larger decrease in percent of sedentary time compared to control group ($p < .05$); ** = significantly larger increase in percent of light activity time compared to control group ($p < .05$); values are displayed as means ± standard deviations; Sedentary ≤ 1.5 MET, Light 1.6-2.9 MET, Moderate 3.0-5.9 MET, Vigorous ≥ 6.0 MET; min = minutes;

than for the control group (see Figure 1). Neither group, *F*(1, 30) = .01, *p* = .907, η_p^2 = .00, or time, *Wilks' F*(1, 30) = .34, *p* = .564, η_p^2 = .01, main effect tests were significant.

Another two-way repeated measures ANOVA (group [2] x time [2]) identified a significant interaction for the percentage change in light activity time from pre and post measures between groups, *Wilks's F*(1, 30) = 5.41, *p* = .027, η_p^2 = .15. This indicated the change in percentage of light activity time for the intervention group was greater than for the control group (see Figure 2). Neither group, *F*(1, 30) = 0.10, *p* = .755, η_p^2 = .00, or time, *Wilks' F*(1, 30) = 1.45, *p* = .238, η_p^2 = .05, main effect tests were significant.

Energy expenditure at work (i.e., avg. kcal/min) was analyzed using a two-way repeated measures ANOVA (group [2] x time [2]). There was a significant interaction for the average change in energy expenditure per minute from pre and post measures between groups, *Wilks's F*(1, 30) = 5.09, *p* = .032, η_p^2 = .15 (see Table 3). There was a significantly greater increase in average energy expenditure per minute for the intervention group than for the control group (see Figure 3). Neither group, *F*(1, 30) = 0.99, *p* = .328, η_p^2 = .03, or time, *Wilks' F*(1, 30) = 0.02, *p* = .897, η_p^2 = .00, main effect tests were significant.

In addition to average energy expenditure, average MET level was analyzed by a two-way repeated measures ANOVA (group [2] x time [2]). There was a significant interaction for average MET level from pre and post measures between groups, *Wilks's F*(1, 30) = 4.82, *p* = .036, η_p^2 = .14 (see Table 3). The increase in average MET level for the intervention group was greater than for the control group (see Figure 4). Neither

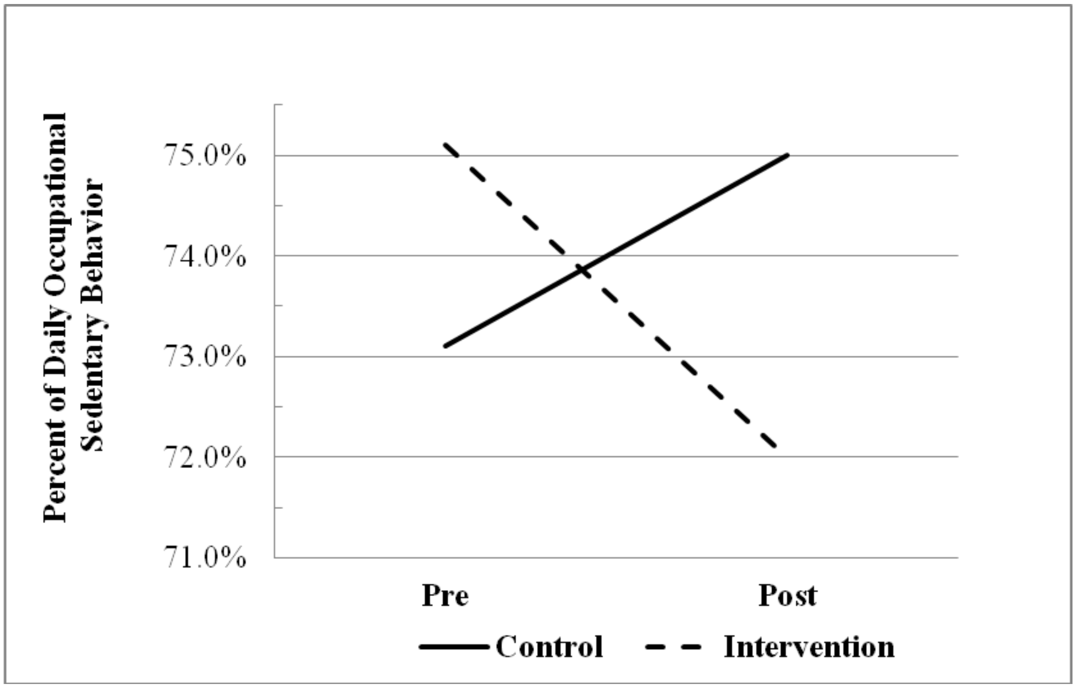

Figure 1. Significant interaction between groups and change in work time (percent) spent in sedentary behavior ($p < .05$).

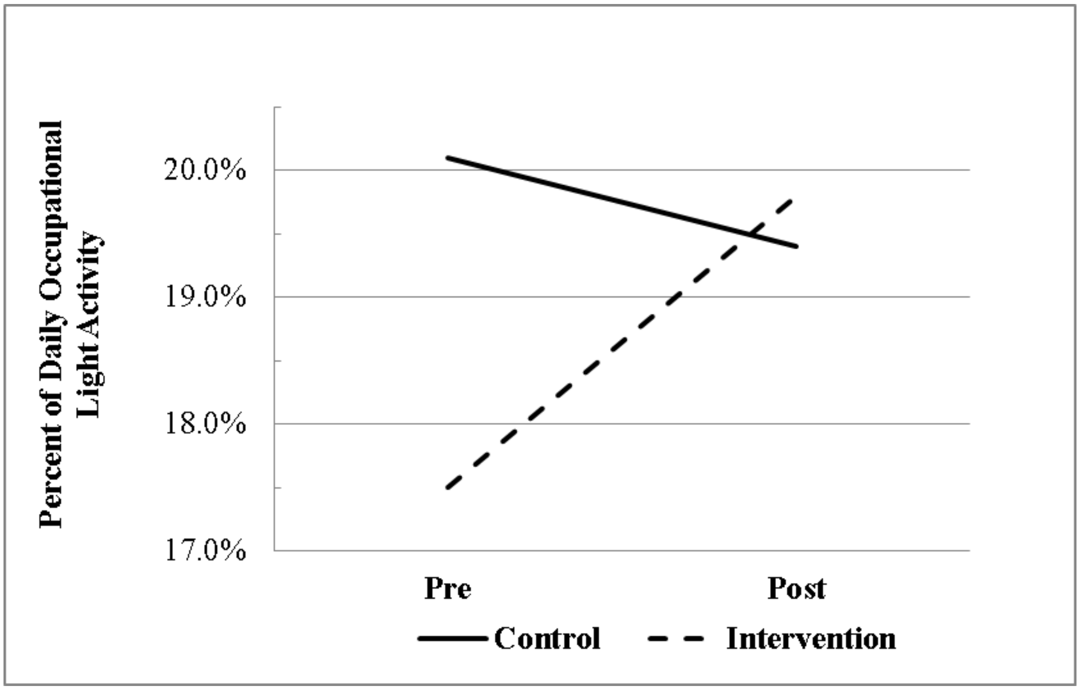

Figure 2. Significant interaction between groups and change in work time (percent) spent in light activity (p < .05).

Table 3

Daily Average Energy Expenditure (kcal/min) and Average MET Level Values at Work

	Control		Intervention	
	Pre	Post	Pre	Post
EE	1.68 ± .30	1.63 ± .32	1.71 ± .18	1.77 ± .22*
MET	1.40 ± .32	1.35 ± .30	1.38 ± .32	1.43 ± .36*

Note. * = significantly greater increase than control group ($p < .05$). Values are displayed as means ± standard deviations; EE = energy expenditure; MET = metabolic equivalent task.

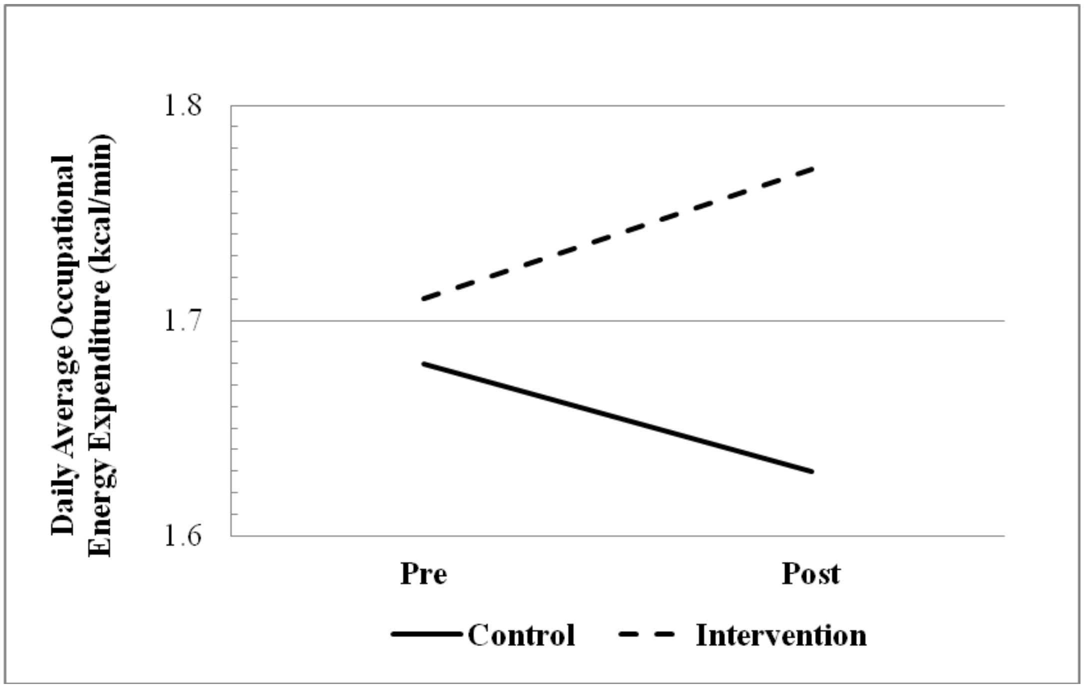

Figure 3. Significant interaction between groups and change in daily occupational energy expenditure ($p < .05$).

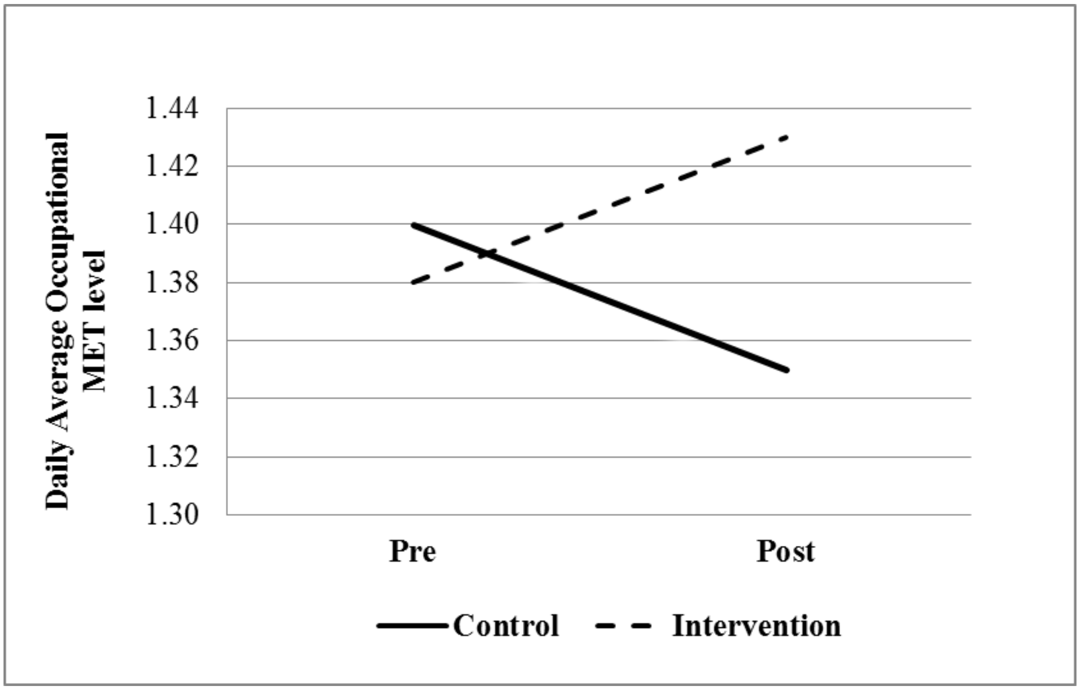

Figure 4. Significant interaction between groups and change in daily occupational MET level ($p < .05$). *Note.* MET = metabolic equivalent task

group, *F*(1, 30) = 0.07, *p* = .79, η_p^2 = .00, or time, *Wilks' F*(1, 30) = .01, *p* = .944, η_p^2 = .00, main effect tests were significant.

Discussion

The one week intervention in the current study, resulted in a daily average reduction of occupational sedentary behavior (3.1%) that is consistent with data from other studies (3 – 5%) implementing behavioral strategies to reduce sedentary time (Gardiner et al., 2011; Kozey-Keadle et al., 2012; Otten et al., 2009). The results of this study imply behavioral strategies, specific only to the workplace, elicit a similar effect as behavioral strategies implemented during other times throughout the day (e.g., leisure time).

While other researchers have measured decreases in sedentary time or increases in moderate physical activity, few studies have included measured changes in light activity. Increased light activity in the current study replaced nearly 75% of the decreased occupational sedentary behavior. This 2.3% increase in light activity was similar to the 3.1% increase noted by Otten et al. (2009), who focused on decreasing leisure time sedentary behavior. The behavioral strategies used in the current study included typical goals of light activity to replace sedentary time. For example, common goals selected by the participants in this study included standing up when they talked on the phone or when someone approached their desk. Also, some participants set a reoccurring timer to remind them to stand up or take a walk down the hall for a drink of water. As a result of setting goals, consisting mostly of light activities, it was anticipated light activity would replace most, if not all, of the reduction in sedentary time.

The change in MET level was consistent with an increase in light activity and increase in average energy expenditure (kcal/min). Subjective measures of MET levels, based on the physical activity compendium (Ainsworth et al., 2011), are often used to report changes in activity level. For example, occupational typing and light effort sitting tasks usually reflect MET levels from 1.3 – 1.5 (Ainsworth et al., 2011). When an office worker stands to talk, file papers, or walk around, MET levels may increase to 2.0 – 3.0 METS (Ainsworth et al., 2011). The objectively measured change in MET levels in the current study, being greater in the intervention group than in the control group, reflect more time being spent standing or slowly walking in office space. Objectively measured MET values are not commonly used, likely because of the required equipment to measure them. The current study provides one of the first attempts to objectively track changes in sedentary and light MET levels in office workers. This is important because increasing the average occupational MET level can help classify workers as being lightly active instead of sedentary.

The change in energy expenditure in the current study was in harmony with the change of energy expenditure measured by Otten et al. (2009). Otten et al. (2009) found energy expenditure to increase approximately 0.08 kcal/min (119 kcal/1 day * 1 day/1440 min). The current study evaluated occupational energy expenditure to increase .06 kcal/min (1.77 kcal/min [post] – 1.71 kcal/min [pre]) and this change in the intervention group was significantly greater than the change in the control group.

Although it is unknown if the changes documented in the current study can be maintained and lead to meaningful health changes, the importance of this study was to encourage the development of feasible strategies to decrease sedentary behavior and increase energy expenditure among sedentary workers. With the rising number of sedentary jobs, average energy expenditure in the workplace has decreased approximately 142 kcal/day over the past 50 years (Church et al., 2011). These calories not being expended in the workplace on a daily basis are associated with the trending increase of body mass (Church et al., 2011). Comparing post mean energy expenditures of the control (1.63 kcal/min) and intervention (1.77 kcal/min) groups, the current study demonstrated behavioral strategies that reduce sedentary behavior may increase energy expenditure in the workplace by approximately 76 kcals/day (9 hours at the workplace). This amount could offset half of the 142 kcal/day not being expended during working hours as a result of sedentary occupations (Church et al., 2011). While the authors acknowledge there are many variables associated with the increased body mass over the past 50 years, there does appear to be a meaningful case for interventions to increase occupational energy expenditure.

The current study used objective measurements of sedentary behavior to determine the feasibility of behavioral strategies to decrease occupational sedentary time. Although the SWA has been used to monitor sedentary behavior in other studies (Bond et al., 2011; Otten et al., 2009), further cross validation is needed for specific measurements of sedentary and light activities. The current study relied on an internal validation study of sedentary and light physical activity measures using SWA. Using behavioral strategies can be easily implemented and cost effective in a workplace setting. Due to the nature of this study, the findings are limited to implementing behavioral strategies during a single work week in which only female office workers were assessed.

Future studies can evaluate the sustainability of behavioral strategies to reduce sedentary time, and if sustainable, discover the long term health effects of increasing energy expenditure in the workplace. Strategies may also include innovative ways to change the physical environment to promote less sedentary time. Interventions and strategies may be most effective if related to specific occupations that face increased risk of occupational sedentary behavior. Finally, it is important that future studies consider evaluating energy expenditure and body posture as measures of sedentary behavior. This will allow further evaluation of the associations between health and sedentary behavior.

While the long term effectiveness of behavioral strategy programs to reduce occupational sedentary behavior is unknown, there is potential that the effects of replacing sedentary time with light activity and increasing energy expenditure can be meaningful. Overall, this study demonstrated it is feasible to change sedentary time, light activity, daily MET levels, and daily average energy expenditure in the workplace. The promotion of effective strategies to reduce occupational sedentary time may lead to sustainable improvements in occupational energy expenditure and health benefits.

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Appendix for Study II

Appendix A

Intervention Brochure

How Can You Reduce Your Sit & Be More Fit?

Suggestions:

- Stand up whenever someone comes into your office
- Stand up to talk on the phone
- Set an hourly timer to remind you to take a break
- Relocate an office supply to the other side of the room.
- Occasionally walk to your colleague's office to deliver a message instead of phoning or emailing
- Take your lunch break outside of your office
- Use a restroom located a little further away

Office Evaluation:

- What office tasks require you to sit?
- What tasks can you perform while standing up?
- **What in your office can help you decrease sedentary time?**
- What times during your office hours are you most likely to succeed in reducing sedentary behavior?

Personal Goals:

Track Your Progress

M: ____________________

T: ____________________

W: ____________________

Th: ____________________

F: ____________________

Reduce Your Sit & Be More Fit!

Decreasing sedentary time in the workplace.

Stop sitting & stand up for yourself!

What is sedentary time?

Sedentary time is when you are lying or sitting.

Do I sit too much at work?

Sitting at Work:	Hours
Computer	
Reading	
Meetings	
Doing paper work	
Talking on the phone	
Talking in person	
Eating	
Other	
Total:	

Sitting Time at Work

Average	High	Very High
< 3 hrs	3 to 5 hrs	$\geq$ 6 hrs

Can sitting too much affect my health?

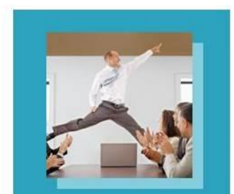
YES! Research has shown sedentary behavior is associated with an increased risk of mortality, high blood sugar, type II diabetes, obesity, increased waist circumference, hypertension, heart disease, high cholesterol, and some cancers.

What if I exercise?

Even if you exercise, it is still important to decrease your sedentary behavior. If you exercise regularly, but are sedentary the rest of the day, you are known as an "active couch potato" and are still at high risk of poor health.

Facts About Sedentary Behavior

- Too much sitting may lead to low back pain.
- Almost 2 out of every 3 people who sit 6 or more hours a day at work are overweight or obese.
- A 10% increase in sedentary time can lead to a 3.1 cm increase in waist circumference.
- Being sedentary can lead to fat gain from over eating.
- Obese individuals who sit for 3/4 of the day, have double the risk of all-cause mortality than obese individuals who sit 1/2 of the day.
- Some evidence suggests sitting at work is associated with an increased risk of ovarian cancer, breast cancer, and colorectal cancer.



Stop sitting and stand up for yourself!

Appendix B

IRB Letter of Approval

May 15, 2012

Joel Reece, Jennifer Caputo, Vaughn Barry, Dana Fuller, Ryan Conners, Saori Ishikawa
Department of Health and Human Performance
jdr5f@mtmail.mtsu.edu , jenn.caputo@mtsu.edu

Protocol Title: "THE FEASIBILITY OF BEHAVIORAL STRATEGIES ON REDUCING SEDENTARY TIME AND INCREASING ENERGY EXPENDITURE IN THE WORKPLACE"

Protocol Number: **12-316**

Dear Investigator(s),

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under the 45 CFR 46.110 Category 7.

Approval is granted for one (1) year from the date of this letter for 50 participants.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. **If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance (c/o Emily Born, Box 134) before they begin to work on the project.** Any change to the protocol must be submitted to the IRB before implementing this change.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918.

You will need to submit an end-of-project form to the Office of Compliance upon completion of your research located on the IRB website. Complete research means that you have finished collecting and analyzing data. **Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date.** Please allow time for review and requested revisions. Your study expires **May 15, 2013**.

Also, all research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Emily Born

Emily Born
Research Compliance Officer
Middle Tennessee State University

Appendix C

Informed Consent

MTSU
IRB Approved
Date: 5/15/2012

Principal Investigator: Joel Reece
Study Title: Feasibility of behavioral strategies on reducing sedentary time and increasing energy expenditure in the workplace
Institution: Middle Tennessee State University

Name of participant: ________________________________ Age: ________

The following information is provided to inform you about the research project and your participation in it. Please read this form carefully and feel free to ask any questions you may have about this study and the information given below. You will be given an opportunity to ask questions, and your questions will be answered. Also, you will be given a copy of this consent form.

Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

For additional information about giving consent or your rights as a participant in this study, please feel free to contact the MTSU Office of Compliance at (615) 494-8918.

1. **Purpose of the study:**
   You are being asked to participate in a research study because there is a need to measure the feasibility of behavioral programs in the workplace.

2. **Description of procedures to be followed and approximate duration of the study:**
   (Visit 1) According to your convenience, you will be met in your workplace on a Friday where your height, weight, and age will be measured. Also at this time, you will be asked to complete a simple questionnaire. You will be given an armband to wear for 10 consecutive days during all hours except in water activities (e.g., showering, etc…). In addition to wearing this armband, you will be given a log to record when you arrive at work and when you depart.
   (Visit 2) Immediately following the 10 days of wearing the armband, you will be met again in your office. This visit will take place on a Monday morning when you first arrive to work. At this time you will be briefly met (maximum of 20 minutes) by the researcher who will replace the armband with a new one and supply a new log to record your arrival and departure from work. This office visit may include educational material and an evaluation of your office in relation to current office behaviors. You will be asked to wear the armband for 7 more days during all hours except in water activities (e.g., showering, etc…).
   (Visit 3) On the Monday following the second visit, the researcher will again meet you in your office at your convenience to pick up the armband and ask you to complete a simple questionnaire. At this time the researcher will debrief you about the study and obtain your work log. If you did not receive educational material and an office evaluation during the second visit, you will have the opportunity during this visit.

3. **Expected costs:**
   There is no cost to you for you participation.

4. **Description of the discomforts, inconveniences, and/or risks that can be reasonably expected as a result of participation in this study:**
   While there are no apparent risks for participating, you may experience some discomfort or inconveniences from logging your hours at work and wearing the armband.

5. **Compensation in case of study-related injury:**
   MTSU will not provide compensation in the case of study related injury.

Middle Tennessee State University Institutional Review Board
Informed Consent Document for Research

6. **Anticipated benefits from this study:**
   a) The potential benefits to science and humankind that may result from this study are the ability to objectively measure the feasibility of behavioral programs in the workplace and lead to future research designed for intervention in the workplace.
   b) The potential benefits to you from this study are learning about workplace behaviors.

7. **Alternative treatments available:**
   There are no alternative treatments available.

8. **Compensation for participation:**
   There is no monetary compensation for participating in this study.

9. **Circumstances under which the Principal Investigator may withdraw you from study participation:**
   If week to week work hours are not consistent or wear time of the monitor is inadequate, the principal investigator may withdraw you from study participation.

10. **What happens if you choose to withdraw from study participation:**
    There are no consequences for withdrawing from the study.

11. **Contact Information.** If you should have any questions about this research study or possible injury, please feel free to contact Joel Reece at 801-234-0973 or my Faculty Advisor, Dr. Caputo at 615-898-5547.

12. **Confidentiality.** All efforts, within reason, will be made to keep the personal information in your research record private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, Federal Government Office for Human Research Protections, if you or someone else is in danger or if we are required to do so by law.

13. **STATEMENT BY PERSON AGREEING TO PARTICIPATE IN THIS STUDY**
    I have read this informed consent document and the material contained in it has been explained to me verbally. I understand each part of the document, all my questions have been answered, and I freely and voluntarily choose to participate in this study.

________________ ________________________________
Date Signature of patient/volunteer

Consent obtained by:

________________ ________________________________
Date Signature

____
Printed Name and Title

Appendix D

Hour Log for Participants

Log what time you arrived to work and what time you left

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Time Arrived:							
Time Departed:							

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
Time Arrived:							
Time Departed:							

CHAPTER V

OVERALL CONCLUSIONS

The theme of this dissertation revolved around sedentary behavior and light activity. The first study of this dissertation validated the Sensewear™ armband (SWA) as an objective measure of sedentary behavior and light activity. The second study used objective measures of the validated SWA to determine it was feasible to decrease sedentary behavior and increase light activity, energy expenditure, and metabolic equivalence (MET) level with the use of behavior strategies among sedentary female office workers.

To validate the SWA as a measure of sedentary behavior, its measurements of energy expenditure for sedentary and light activities were compared to indirect calorimetry measurements of energy expenditure of the Oxycon (criterion). Using energy expenditures across all activities (a combination of 6 sedentary and light activities), the SWA was strongly correlated with the Oxycon. This was determined statistically with Pearson correlations and intraclass coefficient corrlations (ICC). However, the strength of the correlations between the SWA and Oxycon varied when evaluating energy expenditure of activities individually. For example, the Pearson correlations and ICC measurements of energy expenditure between the SWA and Oxycon between each activity ranged from $r = .532$ (supine) to $r = .834$ (sitting office work [OW]) and $ICC = .532$ (supine) to $ICC = .807$ (sitting OW), respectfully. Therefore, although overall correlations were strong for all sedentary and light activities assessed as a group, some sedentary and light activities (i.e., supine, standing OW) may not be assessed as accurately.

In addition to validating the SWA by correlations with the Oxycon, the sensitivity of the SWA to detect slight energy expenditure differences between sedentary and light activities was determined. Overall, the SWA was not as sensitive in detecting changes in energy expenditure between activities as compared to the Oxycon. For example, while the Oxycon was able to detect increases in energy expenditure from sitting OW to standing OW, the SWA only trended toward a significant difference in energy expenditure between sitting OW and standing OW. Despite not being as sensitive as the Oxycon to energy expenditure differences between activities, the tendency of energy expenditure to increase from sedentary to light activity from the SWA was similar to the tendency of Oxycon measurements. Energy expenditure measured by the SWA did not significantly differ with the Oxycon while supine, sitting NM, or walking 1 mph, but under-predicted energy expenditure for standing NM, sitting OW, and standing OW.

The SWA can also be used to quantify time spent in sedentary behavior or different physical activity intensity levels. This was done by using the MET value output to classify intensity levels. By using established MET level classifications for sedentary, light, and moderate activity, the classification of activity levels of the SWA were compared to the classification of activity levels of the Oxycon. The SWA correctly classified intensity level based on MET level for all activities performed in the study 88.6% of the time. This measure is important because it can be used to monitor the amount of time spent at a given intensity level. Also, because individual energy expenditure varies, using objectively measured MET values to monitor the time spent at a given intensity may be more precise than using MET values derived from the physical activity compendium.

Only few validated instruments exist that objectively measure sedentary behavior. By validating the SWA to measure energy expenditure during sedentary and light activities, as well as monitor time spent in sedentary behavior or light activity, it can be implemented to measure and monitor sedentary behavior in future research. This may include monitoring populations or individuals to objectively determine time spent in sedentary behavior, or using the SWA to measure the effectiveness of interventions to decrease sedentary behavior.

By using the SWA to monitor changes in sedentary behavior and energy expenditure, the second study conducted in this dissertation documented it was feasible to have greater changes using behavior strategies to reduce sedentary behavior than not implementing behavior strategies among sedentary female office workers. These changes included a greater decrease in sedentary behavior, a greater increase in light activity, greater occupational energy expenditure, and a greater occupational MET level.

The implemented behavior strategies decreased sedentary time by 3.1% (i.e., 75.1% – 72.0%) compared to an increase of 1.9% (i.e., 73.1% – 75.0%) in the control group. Applying this change of sedentary behavior to a full time worker (8 hours of work + 1 hour lunch), 75.1% (405.5 min) to 72.0% (388.8 min) is equivalent to decreasing occupational sedentary time by 16.7 minutes. While it appears feasible to decrease sedentary time, it is unknown if a decrease of nearly 17 minutes at work would result in a positive health impact. Other variables besides total amount of time decreased in sedentary behavior may influence the potential impact on health. For example, the 17 minutes may reflect one 17 minute break (although unlikely in the current study based on the goals set by the participants) or any number of breaks accumulating to 17 minutes. Healy, Dunstan, et al. (2008) reported the number of breaks (minimum of 1 minute) in sedentary time was independent of total sedentary time in its association with health variables. Furthermore, health benefits may depend on what type of behavior or intensity of physical activity replaced the sedentary behavior. While the current study focused on replacing sedentary behavior with goals to become more lightly active, other studies may focus on replace sedentary time with moderate or vigorous activity.

Few studies have actually measured changes in light activity. The implemented behavior strategies increased light activity time by 2.3% (i.e., 17.5% – 19.8%) compared to a decrease of 0.7% (i.e., 20.1% – 19.4%) in the control group. Applying this change of light activity to a full time worker (8 hours of work + 1 hour lunch), 17.5% (94.5 min) to 19.8% (106.9 min) is equivalent to an increase in occupational light activity time of 12.4 minutes. An increase of 12.4 minutes of light activity would account for nearly 75% of the time that replaced sedentary behavior. Because time spent in vigorous activity made up less than 1% of the total time, the remaining portion (25%) of sedentary time would be replaced mostly by moderate physical activity (4.3 min).

By replacing time spent in sedentary behavior with greater intensity levels, the increase in daily average energy expenditure and daily average MET level at work increased greater in the intervention group compared to the control group. Even a slight increase in average energy expenditure at work will lead to greater total energy expenditures over time. For example, the difference in post mean energy expenditure values for the control (1.63 kcal/min) and intervention (1.77 kcal/min) groups could lead to expending an extra 76 kcal a day at work (8 hours of work + 1 hour lunch). This amount would offset more than half of the estimated decrease in occupational energy expenditure (142 kcal/day) due to more sedentary jobs over the past 50 years (Church et al., 2011). Furthermore, the decrease in occupational energy expenditure is associated with the increase in body mass over the same time period (Church et al., 2011), lending potential implications that behavior strategies to reduce sedentary time in the workplace may play an important role in decreasing obesity rates.

As a result of these studies, future research can objectively evaluate changes of energy expenditure. Using the SWA, researchers can accurately and objectively monitor sedentary behavior and light activity. Now that behavior strategies have been documented as a feasible way to reduce sedentary behavior, long term evaluations of sedentary behavior can be observed to determine the sustainability and potential health benefits of behavior strategies on reducing sedentary behavior. Innovative strategies to decrease sedentary time may also be specialized to populations or occupations at high risk of being sedentary.

In conclusion, although the long term health implications of behavioral strategy programs to reduce occupational sedentary behavior are unknown, there is potential that the effects of replacing sedentary time with light activity and increasing energy expenditure can be meaningful. This dissertation not only validated a method to measure sedentary behavior, but also demonstrated a feasible way to have greater changes in sedentary time, light activity, daily MET levels, and daily average energy expenditure in the workplace compared to not implementing behavior strategies. The promotion of these and other strategies to reduce occupational sedentary time may lead to sustainable improvements in occupational energy expenditure and possible health benefits.

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