Spring 2015

The association between sleep quality, physical inactivity, and risk of developing metabolic syndrome

Matthew Scott
James Madison University

The Association between Sleep Quality, Physical Inactivity, and Risk of Developing Metabolic Syndrome

Matthew C. Scott

A Thesis submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

In

Partial Fulfillment of the Requirements

for the degree of

Master of Science

Department of Kinesiology

May 2015

Acknowledgements

I would like to thank Dr. Trent A. Hargens for serving as my Committee Chair. I am very grateful for the for his guidance as well as constant support and feedback throughout this process.

I would also like to extend my gratitude to Dr. Mikel K. Todd and Dr. Elizabeth S. Edwards for serving as members of my thesis committee as well as providing constructive feedback and support during this time.

Additionally, I would like to thank all of my Kinesiology professors as well as my current/former fellow Kinesiology graduate students for their constant support.

Finally, I would like to thank my family for their everlasting love and support throughout my entire time in graduate school.

Table of Contents

List of Tables

List of Figures

Abstract

Purpose The aim of this study is to assess the independent effects of sedentary time, sleep quality, and physical activity on risk factors for Metabolic Syndrome (MetS) in college students.

Methods 40 college aged students were recruited from James Madison University. Height, weight, blood pressure, waist circumference, and body composition were assessed on visit 1. Blood pressure, blood glucose, and lipid profile were assessed on visit 2. Subjects were required to wear an Actigraph GT3x accelerometer, which measured physical activity, sedentary time, and sleep quality for 7 days and nights. Univariate Pearson correlation analyses were performed to determine the relationship between sedentary, sleep quality, and physical activity variables with MetS risk factors. Variables for each category were determined to have the greatest correlation with MetS, and were used as independent variables in a step-wise, multiple linear regression to determine the best predictors for each MetS risk factor. Each variable was then ranked into tertiles and ANOVA/ANCOVA was performed with each MetS risk factor. Variables determined to have the greatest correlation with MetS were evaluated as covariates. A priori statistical significance was set at $p<0.05$.

Results Correlation analyses indicated the strongest predictors of MetS to be time per sedentary bout, time per awakening, step counts, and MVPA. Step counts and time per sedentary bouts were significant predictors of waist circumference ($R^2= .406$; $p<0.01$). Step Counts and time per awakening were significant predictors of systolic blood pressure ($R^2 = 0.49$; $p<0.01$) and total MetS risk factors ($R^2= 0.278$; $p=.002$). Step counts was the only significant predictor of HDL ($R^2=0.132$; $p=0.025$). Waist circumference was

greater in the lowest time per sedentary bout Tertile (83.04 ±11.3) compared to the highest Tertile (72.1 ±8.5). Systolic blood pressure was greater in the highest time per awakening tertile (124.4 ±12.3) compared to the lowest Tertile (111.8 ±10.2). Blood glucose was greater in the moderate time per awakening Tertile (84.4 ±6.9) compared to the lowest Tertile (77 ±7.4). Waist circumference was greater in the lowest time spent in MVPA Tertile (87.03 ±11.1) compared to the moderate (76.3 ±7.1) and highest Tertiles (71.9 ±9.3). Systolic blood pressure was greater in the lowest and moderate tertiles of time spent in MVPA Tertiles (125.5 ±12.6 and 121.7 ±8.6, respectively) compared to the highest Tertile (110.6 ±7.6). HDL was greater in the highest tertile of time spent in MVPA (68.6 ±13.1) compared to the moderate Tertile (60.4 ±9.4).

Conclusion Daily step counts and increased time spent in MVPA has the largest influence on preventing MetS and its respective risk factors in college students.

Chapter 1
Introduction

Physical activity is recognized as necessary for human's well-being (2). To achieve health benefits from physical activity it is recommended that Americans accumulate 150 minutes a week of moderate-intensity activity, 75 minutes per week of vigorous intensity exercise, or a combination of the two (2, 9). The benefits that come from adhering to these guidelines can occur in healthy individuals, those at risk for developing certain diseases, and in those who already have a diagnosed condition. While recommendations for physical activity have been set, a majority of the United States population fails to meet or adhere to them. According to the Center for Disease Control (CDC), in 2014 only 48% of Americans met the physical activity guidelines previously mentioned (13). Due to the increased occurrence in sedentary behavior, research has focused on the health risks associated with physical inactivity.

Physical activity is known as a modifiable risk factor for early mortality and the development of chronic disease (2). As early as 1986, as part of the Harvard Alumni Study, Paffenbarger et al. identified that increased physical activity will significantly lower mortality rates (54). Paffenbarger et al. tracked physical activity and mortality rates of 16,936 subjects aged 35-74 from 1962-1978. Relative Risk of death decreased by 54% as energy expenditure increased from 500 to 3,500 kcals per week. More recently, it has been seen that individuals who report at least 1 hour of moderate activity per week have a 33% lower risk of mortality compared to those who report less than 1 hour (56). As intensity and amount of physical activity increase, health benefits such as improved body composition, Low Density Lipoprotein (LDL), High Density Lipoprotein (HDL), blood

pressure, glucose metabolism, and insulin sensitivity will be seen (67). Byberg et al. assessed changes in physical activities in relation to cardiovascular risk factors in a sample size of 898 men 50 years of age and older who were followed up with after 20 years (11). Byberg et al. found that, through self-report data, 31% of the sample reportedly increased their physical activity and it was associated with significant changes in fasting glucose, HDL, proinsulin and lipid profile. Vaisto et al. reported similar results to Byberg et al. while examining a group of 468 children aged 6-8 (66). Physical activity patterns were compared with a cardiometabolic risk score. This score was generated by a specific formula which took most cardiovascular disease risk factors into consideration. Total physical activity was inversely associated with the cardiometabolic risk score (B= -0.135; p=.004).

While increased physical activity is known to be important for the prevention of chronic disease, specifically cardiovascular disease, recent evidence has indicated that elevated levels of physical inactivity, or sedentary time, will result in increased risk of cardiovascular disease and its individual risk factors, independent of physical activity levels(4, 14, 29, 31, 64), suggesting that sedentary time should be treated as its own entity (31). Sedentary behaviors are classified as activities that involve an energy expenditure of 1.0-1.5 METs (18, 47, 64). Examples of such behaviors include sitting, reclining, or lying down. In a 6-year follow up study assessing sedentary behaviors relationship to obesity and diabetes, Hu et al. assessed 50,277 women with a non-obese BMI at baseline and 68,497 women who at baseline were free from diagnosed diabetes (32). Sedentary behavior was assessed by measuring time sitting at home watching T.V. Data indicated that for each 2 hour per day increment of TV watching, risk of obesity and diabetes

increased 23% and 14% respectively. More objectively than Hu et al., Helmerhorst et al. examined the association between time spent sedentary and insulin resistance and whether that association was independent of moderate-vigorous physical activity (31). 376 middle aged adults (166 men; 210 women) were followed over 5.6 years. Time spent sedentary was found to be significantly and positively associated with fasting insulin (B=.005, 95%, CI, P=0.005). This relationship was further strengthened after adjusting for moderate-vigorous physical activity (B=.004, 95%, CI, P=0.009). These studies highlight the importance of limiting sedentary time versus focusing on increased physical activity only.

Due to the strong association between physical activity or inactivity with individual risk factors for cardiovascular disease, research has also examined these variables relationship with Metabolic Syndrome (MetS). MetS is a cluster of interrelated cardiovascular disease risk factors that include abdominal obesity (Waist Circumference >102cm in men, >88cm in women), elevated triglycerides (≥150mg/dL), low HDL (<40 mg/dL in men, <50mg/dL in women), impaired fasting glucose (≥110mg/dL), and elevated blood pressure (≥130/85mmHg)(2). When found together there is an increased risk of developing cardiovascular disease. In 2010, approximately 22.9% of Americans had been diagnosed with MetS (5). Since 1988 when it was first defined, criteria for MetS have changed frequently because its risks are still not fully understood (15, 17, 20, 22, 25, 43, 48, 65).

Laaksonnen et al. examined leisure time physical activity (LTPA) as a predictor of Metabolic Syndrome (42). MetS and reported physical activity levels were measured in 1,038 male subjects. Physical activity levels were measured via the

Kuopio Ischemic Heart Disease 12-month Leisure Time Physical Activity Questionnaire. Results indicated that men engaging in more than three hours of leisure time physical activity a week were 48% less likely to develop MetS than sedentary men. Even low intensity activity when performed over longer durations throughout the week was associated with a 40% decreased likelihood of developing MetS. Similar to Laaksonnen et al., Yang et al., utilizing a longitudinal study design, examined the effects of physical activity patterns on the development of MetS in 2,060 subjects who were tracked for 9 years (1992-2001) (71). Physical activity was assessed using a self-report questionnaire. Groups were distinguished between being persistently inactive, decreasingly active, increasingly active, and persistently active. Persistently active referred to those classified as active in both 1992 and 2001, increasingly active referred to subjects who were classified as inactive in 1992 and active in 2001, decreasingly active referred to subjects active in 1992 and inactive in 2001, and persistently inactive referred to subjects inactive in both 1992 and 2001. Results showed that over the 9-year period, those who were persistently active and increasingly active were significantly less likely to have MetS. MetS can be largely avoided by replacing sedentary activity with light intensity activity (71).

Chase et al. assessed 54 individuals who were older than 65 years of age (14). Participants underwent a 7-day accelerometer assessment to analyze physical activity and tests to measure for MetS as well as LDL. All but one participant met physical activity recommendations set forth by the American College of Sports Medicine (ACSM); however, data only indicated a significant relationship between sedentary time and LDL. The data presented by Chase et al. indicates that even though an individual may meet the

physical activity guidelines initially mentioned, high amounts of sedentary activity can still have detrimental effects to health. Much like chase et al., Bankoski et al. directly measured the association between sedentary activity and the MetS in 1,367 men and women aged 60 and older (4). Individuals with MetS spent a significantly greater portion of their day sedentary (67.3% vs 62.2%; $p<0.01$), had significantly longer sedentary bouts (17.7min vs 16.7min; $p<0.01$), and had significantly fewer breaks from sedentary bouts (82.3 vs 86.7; $p<0.01$). These results indicate that individuals may avoid MetS by reducing prolonged sedentary time and increasing breaks of sedentary time. This relationship was also analyzed in a meta-analysis conducted by Edwardson et al. who analyzed 10 cross sectional studies (n=21,393) (18). Greater time spent sedentary increased the risk of MetS by 73% (OR 1.73, $p<0.0001$). This growing body of evidence indicates that prolonged daily sedentary behavior is detrimental to health, even when meeting physical activity guidelines.

The previous studies have shown a positive association between sedentary time and risk of developing MetS independent of physical activity, but there is currently insufficient evidence to change recommendations to limit sedentary time. Americans have been found to be sedentary on average for 54.9% of the day and breaks from sedentary behavior have been shown to be beneficial to metabolic risk (47). Healy et al. assessed accelerometry data in combination with anthropometric and blood measures in 168 subjects (mean age 53.4) from the 2004-2005 Australian Diabetes, Obesity, and Lifestyle study (30). They concluded that increased breaks in sedentary time were associated with improved waist circumference (B= -0.16, P=0.026), BMI (B= -0.19, P=0.026), 2-hour plasma glucose (B= -0.18, P=0.025), and triglycerides (B= -0.18, P=

0.029). This evidence helps promote the need to limit sedentary behaviors through increased low energy expenditure throughout the day.

The physiological mechanisms of sedentary physiology causing metabolic dysregulation are not fully understood, however, there are several proposed mechanisms due to human bed rest studies as well as animal restricted movement studies. These methods replicate the most extreme form of physical inactivity. Through them, it has been seen that individuals/animals experience insulin resistance as well as an altered lipid metabolism, which are strong contributors to Metabolic Syndrome (7). Insulin, the key hormone responsible for initiating glucose uptake at rest, follows a specific signaling pathway that activates Glucose Transport Content 4 (GLUT-4). GLUT-4 is a protein that allows glucose uptake into a cell. Dysregulation of this signaling pathway or alterations to GLUT-4 content is termed insulin resistance (7). It is believed that physical inactivity will cause insulin resistance in skeletal muscle cells (7, 16, 27, 51). The specific mechanisms for which physical inactivity interferes with the insulin signaling pathway are still not fully understood, however. One speculated theory is that sedentary time affects the phosphorylation of Protein Kinase B, which is thought to stimulate the mobilization of GLUT-4 (40). Due to the lack of skeletal muscle activity in a physically inactive subject, the function and content of GLUT-4 has been shown to be diminished (49). Megeney et al. compared the GLUT activity of rats with denervated muscle to a control group (49). Results indicated that the GLUT content and function of the experimental group was significantly lower than that of the control (-87.5 to -34.95). Without proper insulin function, with diminished GLUT-4 content/function, or a combination of the two, metabolic dysregulation can occur.

Another proposed mechanism in which physical inactivity may cause metabolic dysregulation is by decreased lipolysis and uptake of lipids (7). Hormone sensitive lipase (HSL) is an enzyme largely responsible for the mobilization of stored lipids. Physical inactivity is thought to diminish HSL activity (1, 7). This alteration causes a decrease in whole body lipolysis and leads to lipid accumulation within the body as well as the accumulation of metabolites, which may also contribute to insulin resistance (1, 7). Much like the effect on HSL, physical inactivity also may diminish lipoprotein lipase (LPL), an enzyme responsible for stimulating the uptake of fatty acids into muscle and adipose. Improper function of LPL will lead to elevated plasma triglyceride levels, or hypertriglyceridemia (7, 8).

Bed rest and animal restricted movement studies provide a foundation for evaluating the physiological effects of physical inactivity and how they contribute to chronic disease. However, these methods replicate the most extreme level of physical inactivity. It is important to consider that daily sedentary time revolves around prolonged periods of sitting or laying, with bouts of movement throughout the day. Typically, these bouts involve more than the movement seen when bed ridden. Therefore, while the mechanisms mentioned provide evidence that sedentary behavior is independently detrimental to health, further research is needed to determine the relationship between daily sedentary time and chronic diseases, such as MetS.

Sleep quality is another common variable associated with chronic disease, including MetS. Sleep makes up approximately one third of an individual's life.(44) Over the past several decades, the diagnosis of sleep disorders and disturbances has risen sharply (44). These disorders and disturbances can occur at any age, making diagnosis

and treatment vital to avoid early onset of chronic disease (12, 21, 24, 46). Grandner et al. conducted a telephone survey to determine sleep complaints in individuals 18 years of age and older (24). After completing the survey in 155,877 participants, they found no difference in sleep quality across age groups. This data indicates that anyone can experience the health detriments of poor sleep.

The overall prevalence of disturbed sleep within the general population is between 35% and 41%, with 56% of those affected continuing to have symptoms in the years following diagnosis(59). Due to the high prevalence of sleep disorders, researchers have begun to focus on the causes, potential risks, and treatment options to limit their severity. Sleep quality is measured by evaluating the sleep variables: sleep latency, the time it takes to purposely fall asleep; sleep fragmentation, the number of micro-arousals per night's sleep; total sleep duration, the total time recorded as asleep; and sleep efficiency, the amount of time actually spent asleep (3, 41, 45, 57, 60, 63). While these variables are all associated with one another, sleep quality is often reported as an overall score or measured through sleep duration (19, 36).

The majority of the literature related to sleep quality focuses on sleep duration. Currently, Americans sleep 25% less than they did 100 years ago (35). This has primarily been a result of changes in lifestyle. Increased work stresses, poorer health status, symptoms of depression, and obesity have all been related to altered sleep duration (35). In 1998, the average sleep time in America was 6.57 hours (35). As a part of the Coronary Artery Risk Development in Young Adults study, Lauderdale et al. examined sleep characteristics among young adults in 2003 and 2004 (44). The sample included 669 eligible participants, with ages ranging from 18-30. Actigraphy

and the Pittsburgh Sleep Quality Index (PSQI) were used as measures of sleep characteristics. Lauderdale et al. concluded that, in this population, average time spent in bed was approximately 7.5 hours, while time asleep was 6.1 hours.

Poor sleep quality has been associated with increased risk of cardiovascular disease when measured via total sleep duration. There is a growing body of evidence indicating that overall poor sleep quality and sleep duration are associated with elevated BMI, impaired glucose metabolism, hypertension and dyslipidemia, as well as increased risk for mortality and morbidity from cardiovascular disease (6, 10, 12, 19, 23, 39, 55, 70). Research indicates that there is a U-shaped relationship between sleep duration and the risk factors previously mentioned, indicating that both short and long sleep are detrimental to health. While thresholds of sleep duration vary in each study, short sleep is typically defined as less than 6 hours and long sleep is typically defined as greater than 8 hours (6, 10, 12, 23, 26, 39, 55).

Several studies have indicated a relationship between sleep duration and mortality. Kronholm et al. found an association between self-reported sleep duration, all-cause mortality, and cardiovascular mortality and morbidity when sleep duration was measured (39). In this study, 25,025 subjects met the inclusion criteria at the end of the 35-year period. Kronholm et al. confirmed the u-shaped relationship between sleep duration and total mortality. Data indicated that those who slept 5 hours or less had a hazard ratio of 1.20 ($p=.12$) and 1.33 ($p=0.01$) for men and women respectively, and those who slept 10 or more hours had a hazard ratio of 1.27 ($p=.14$) and 1.76 ($p<0.01$) for men and women respectively. When compared to those who slept 6 hrs, 7-8 hrs, and 9 hrs, these groups had the highest rates of mortality from cardiovascular

disease. Sabanayagam & Shankar supported the findings of Kronholm et al. by analyzing data from the National Health Interview survey in 2005 (55). In their study, 30,397 participants 18 years of age and older self reported sleep duration into categories of 5 hours or less, 6 hours, 7 hours, 8 hours, or 9 or more hours. Participants also self-reported incidence of myocardial infarction, angina, and/or stroke. Compared with 7 hours of sleep, the odds ratio of CVD was 2.20, 1.33, 1.23, and 1.57 for sleep durations of 5 hours or less, 6 hours, 8 hours, and 9 or more hours respectively. These studies indicate a positive association between shorter and longer sleep durations and cardiovascular disease.

In addition to cardiovascular mortality/morbidity, sleep duration has also been associated with elevated BMI or obesity. Van den Berg et al. conducted a study including 983 subjects 55 years of age and older, investigating this relationship (6). The subjects wore an Actiwatch for objective measures of sleep duration for 5-7 nights while also keeping a sleep diary. Short and long sleepers were found to be at greater risk of being obese when compared to those who slept 7-8 hours, having ORs of 2.76 and 2.93 respectively. Researchers confirmed a U-shaped association between sleep duration and BMI/obesity. In a similar manner to Van den Berg et al., Gangwisch et al. examined the relationship between inadequate sleep and obesity by analyzing data on 9,588 subjects who had been followed by the National Health and Nutrition Examination Survey (23). Subjects self-reported hours of sleep while BMI was recorded over time. Gangwisch et al. found that individuals who reported getting 2-4, 5, or 6 hours of sleep per night had a 235%, 60%, and 27% greater likelihood to be obese, respectively. The relationship between sleep duration and obesity seen in these previous

studies is supported by a meta-analysis performed on adults and children by Cappucio et al (12). For children, 13 populations from 12 studies, ages ranging from 2 to 20 years, were analyzed (30,002 participants). For adults, 22 populations from 17 studies, ages ranging from 15-102 years, were analyzed (604,509 participants). They concluded that in both child and adult populations, there was significant association between short duration sleep and obesity. The pooled OR for short duration sleep and obesity was 1.89 for children and 1.55 for adults. When conducting a pooled regression analysis in adults, a reduction in one hour of sleep per day would be associated with a 0.35 kg/m^2 increase in BMI.

Lastly, other consequences of short and long duration sleep include impaired glucose metabolism, hypertension, and dyslipidemia. Buxton & Marcelli assessed the association between short and long sleep duration with obesity, diabetes, hypertension, and cardiovascular disease (10). Data was analyzed from the 2004-2005 National Health Interview Survey. A sample of 56,507 participants 18-85 years of age self-reported sleep quality and presence of cardiovascular disease risk factors. When compared to those sleeping 7-8 hours per night, short and long sleep were significantly associated with the probability of developing obesity (6% and 3% respectively), high blood pressure (2.4% and 1.1% respectively), and cardiovascular disease (2.5% and 1.1% respectively). A positive association between short and long sleep and the probability of developing diabetes was found, but was not statistically significant. Much like Buxton & Marcelli, Yaggi, Araujo, & McKinlay compared sleep duration and metabolic consequences (70). However, the relationship between sleep duration and the development of type 2 diabetes was the only association made. A

cohort of 855 men from the Massachusetts male aging study without diabetes at baseline in 1987-1989 were followed until 2004. Subjects self-reported average sleep per night and were asked if they had developed diabetes. Men reporting less than 5 hours and an average of 6 hours per night were twice as likely to develop diabetes, and those reporting sleep duration longer than 8 hours were more than three times as likely to develop diabetes. Across the literature it is agreed upon that altered sleep durations will have a negative impact on health measures such as obesity, blood glucose, and hypertension, as well as put individuals at an increased risk of developing Cardiovascular Disease.

While much of the literature on sleep quality and cardiovascular disease risk factors is related to sleep duration, sleep quality does not equal sleep duration (28). Sleep quality studies assess an overall sleep quality score or analyze all sleep quality parameters. Much like physical inactivity, when associating sleep quality with health risk, assessing MetS is a common variable. Hung et al. studied the association between self-reported sleep quality and MetS (33). 3,435 subjects 39 years of age or older from the Prevention Health Center of National Cheng Kung University hospital, self-reported sleep quality via the Pittsburgh Sleep Quality Index (PSQI) and underwent MetS testing. A higher score on the PSQI indicates poorer sleep quality. Data indicated that subjects with MetS had significantly higher global PSQI scores (6.7±3.2 vs 6.1±2.4) as well as a greater prevalence of poor sleepers (63.4% vs 53.5%) in comparison to those without MetS. In a similar fashion to Hung et al., Jennings et al. conducted a study associating self-reported sleep quality and MetS with a sample of 210 subjects with a mean age of 46 (36). The PSQI and measurements to

test for MetS after a 12 hour fast were performed. For every 2.6 point increase on the PSQI, a participant was 1.44 times more likely to develop or meet the criteria for the MetS.

Few studies have related the individual criteria of sleep quality with MetS. Mesas et al. examined the relationship between sleep quality and MetS (50). In their study, 10,342 middle aged individuals self reported sleep quality by identifying difficulty falling asleep and difficulty maintaining sleep. Difficulty falling asleep was the only significant factor associated with MetS. Ekstedt, Akerstredt, & Soderstrom evaluated the effects of microarousals, or sleep fragmentation, during sleep and their association with increased levels of lipids, cortisol, and blood pressure (19). Polysomnography, blood samples, salivary cortisol, and blood pressure were conducted in 24 people with a mean age of 30. An increased number of arousals was the only significant predictor for impairments involving systolic blood pressure, diastolic blood pressure, plasma cortisol, total cholesterol, and LDL. Researchers suggested that sleep fragmentation may have the biggest effect on risk factors for MetS. While these two studies disagree about which aspect of sleep quality is more important, there is a general agreement that poor sleep quality is associated with having or developing MetS.

There are several limitations to the research focusing on sleep quality, physical inactivity, and MetS. One limitation of the research is that a majority of data is found using questionnaires and surveys. While these techniques provide valuable information to the general body of literature, they are affected by bias, cognitive ability, variations in parameters, recall ability, community expectations, and self miss-perception as well

as demographic variables such as age, ethnicity, work stress, education and socioeconomic status (28, 34, 44, 45, 60, 61). Due to the several external influences on non-experimental data, especially the disagreement between definitions and parameters, it is difficult to generalize results from these studies. Within these studies it is normally alluded to that their findings should be confirmed using objective measures that would allow for various studies to be compared.

Secondly this area of research focuses on older adults, children, and those with diagnosed disease. Children are targeted due to the hormonal and behavioral changes that occur as a result of maturation, while older adults are targeted because of the increased risk of morbidity and mortality. A population that is not as well researched is young adults, although these individuals are at an increased risk for poor sleep quality, physical inactivity, and development of the MetS as a result of behavioral and lifestyle changes that occur when moving away from parental supervision.

Some evidence has indicated that increased physical activity levels in younger adults will result in substantial health benefits. In a sample with a mean age of 20.3 years, Schilter and Dalleck examined the effects of self report physical activity on MetS and cardiovascular disease risk factors. Results indicated that as physical activity levels and intensities increased, there was an increase in HDL levels as well as lower blood glucose. Morrell et al. added to this evidence by assessing activity levels via pedometry. Results indicated that a higher step count per day resulted in a decreased prevalence of MetS risk factors. While this evidence has shown the effects of physical activity in college aged students, no evidence has examined the effects of sleep quality and physical inactivity in this population. The health risks of these

variables have been described and it is of vital importance to determine whether these effects are present in a younger population. This population should be a focus in order to prevent early morbidity and/or mortality (20, 24, 53, 69).

To date, no published literature has objectively assessed whether physical inactivity or sleep quality has a greater effect on MetS independent of the other. Examining these relationships has the potential to shed light on the importance of sleep quality and limiting sedentary time in reducing the risk of developing MetS through the improvement of metabolic risk factors. Therefore, the purpose of this study is to objectively examine the association between sleep quality, sedentary time, and the risk of developing MetS in college students. It is hypothesized that physical inactivity will have a greater effect on MetS than sleep quality.

Purpose:

Objectively examine the association between sleep quality, sedentary time, and risk of developing the Metabolic Syndrome in college students.

Hypothesis:

It is hypothesized that physical inactivity will have a greater effect on MetS than sleep quality.

Assumptions:

1) Participants will wear the physical activity and sleep quality monitors at all appropriate times.

2) Participants will not alter their physical activity patterns, sleep patterns, or lifestyle behaviors while they are being monitored.

3) Physical activity and sleep quality monitors (Actigraph GT3x) are valid and reliable.

Delimitations:

1) This study will focus on college aged students between the ages of 18-26.

2) Participants must be relatively healthy. Those with diagnosed cardiovascular, metabolic, or pulmonary disease will not be included.

Limitations:

1) Findings cannot be generalized to other age groups.

2) The entire population will not be represented because college students who have diagnosed cardiovascular, pulmonary, or metabolic disease will not be included.

3) When used to measure sleep variables, accelerometers may not be able to distinguish between the participant being asleep and not moving while laying in bed.

Operational Definitions:

1) *Physical Activity*- any bodily movement produced by skeletal muscle contractions that results in a substantial increase in caloric requirements above resting values.

2) *Sedentary Time/Behavior*: activities that require an energy expenditure of 1.0-1.5 METS.

3) *Sleep Quality*- assessment of the following variables:

- Sleep Onset Latency: The time it takes to fall asleep.
- Sleep Fragmentation: The number of micro-arousals per night's sleep.
- Total Sleep Duration: The total time recorded as asleep.
- Sleep Efficiency: The amount of time actually spent asleep.

4) *Metabolic Syndrome (MetS)*- having at least three of the following criteria; Central Obesity (Waist Circumference >102cm in men, >88cm in women);

Hypertriglyceridemia (≥150mg/dL); Low HDL (<40 mg/dL in men, <50mg/dL in women); Elevated Blood Pressure (≥130/85mmHg); Elevated Fasting Glucose (≥110mg/dL)

Chapter 2
Methodology

Study Design and Participants:

College aged students between the ages of 18 and 26 were recruited through email, flyers, and communication on University property. Exclusion criteria of the study included individuals who have been diagnosed with cardiovascular, metabolic, or pulmonary disease. A total of 42 subjects were recruited.

Participants were given one Actigraph GT3X+ accelerometer (Actigraph, Pensacola, Florida) to objectively record daily physical activity and sleep quality, and wore it for 7 consecutive days/nights. During the waking hours of the day, the accelerometer was worn on the participants' right hip to assess physical activity. When the participant attempted to sleep and during the night's sleep, the accelerometer was worn on the non-dominant wrist. Participants were instructed to wear the physical activity monitor from awakening to the attempt to sleep, only removing it when bathing or doing water activities. When the participant attempted to fall asleep, they moved the accelerometer from the right hip to the non-dominant wrist. Along with wearing the Acitgraph accelerometer to measure sleep quality, participants recorded both bed time and wake time on a document provided. Participants were required to come to the James Madison University Kinesiology Human Performance Lab (HPL) on two separate occasions.

Visit 1

On their first visit, the first item that was read, discussed, and signed was the informed consent. Participants were then given a health history questionnaire, the

Berlin questionnaire which assessed snoring characteristics, the Epworth Sleepiness Scale which determined level of daytime sleepiness, and the International Physical Activity Questionnaire Short Form (IPAQ) which assessed current physical activity patterns, to fill out. Blood pressure was then measured after 5 minutes of seated rest, and was measured according to ACSM procedures (2). Participants had their body mass and height measured using a physician's scale and stadiometer, respectively. Waist Circumference was taken according to the American College of Sports Medicine guidelines using a cloth tape measure with spring-loaded handle, to reduce compression of the skin (2). Lastly, body composition was analyzed using a Dual Energy X-Ray Absorptiometer (DEXA). The DEXA scan provided total body fat percentage, total fat mass, total lean mass, fat free mass, estimated visceral fat mass, as well as estimated visceral fat volume. The participant was symmetrically aligned within the outer lines of the bed, with their spine aligned with the center line. After all measures were taken, the accelerometer was programmed and instructions were provided to the subject on proper use.

Visit 2

On visit 2, a week after visit one, participants returned the accelerometer. For this visit, participants were required to fast for 8-12 hours prior to coming to the HPL. A resting blood pressure was taken after 5 minutes of seated rest, according to ACSM procedures(2), followed by a finger stick to assess for blood lipid values and blood glucose. Polymer Technology Systems lipid panel and glucose test strips were used in combination with a Cardiochek Portable Blood Test System to assess for the variables

previously mentioned. 40 and 15 microliter samples were collected for the lipid panel assessment and glucose assessment, respectively. After all assessments were completed, Framingham Risk Scores were calculated (68).

Measures:

Physical Activity. The Actigraph GT3X is a small activity monitor that measures accelerations throughout the day which are expressed as activity counts. These activity counts were categorized as: sedentary, light activity, moderate activity, or vigorous activity using investigator-specified thresholds. Activity counts were summed over a 60 second epoch. The validity and reliability of the Actigraph GT3X accelerometers have been previously described (37, 38, 58). Once data is downloaded from the device, daily wear time was determined by removing periods of non-wear time defined as greater than 20 minutes of no detected movement. Blocks of time specified as sleep periods during the sleep analysis were also be treated as non-wear time. The data received could only be summarized if daily wear time was at least 10 hours. Daily average time spent in sedentary, light, moderate, vigorous, very vigorous, and MVPA intensities was determined. Average daily values were also determined in the following variables: energy expenditure, number of sedentary bouts, time in sedentary bouts, number of sedentary breaks, time of sedentary breaks, step counts, and total counts in Freedson (1998) bouts.

Sleep. The validity and reliability of using the Actigraph device as a measure of sleep quality has been previously described (3, 52, 62). Data collected by the accelerometer using a 60 second epoch was downloaded and analyzed by Actigraph

software. To help determine certain sleep-wake variables, bedtime and wake time were recorded using a sleep diary. The variables that were analyzed were sleep onset latency, sleep efficiency, time in bed, sleep time, wake after sleep onset, number of awakenings, and time per awakening.

Metabolic Syndrome (MetS). MetS was assessed using the ATP 3 criteria. To be diagnosed with the MetS, an individual must meet at least three of the following criteria: Central Obesity (Waist Circumference >102cm in men, >88cm in women); Hypertriglyceridemia (≥150mg/dL); Low HDL (<40 mg/dL in men, <50mg/dL in women); Elevated Blood Pressure (≥130/85mmHg); Elevated Fasting Glucose (110mg/dL)(2). Body composition and blood samples collected were utilized as previously described to assess for diagnosis.

Statistical Analyses

Univariate Pearson correlation analyses were performed to determine the relationship between sedentary, sleep quality, and physical activity variables with MetS risk factors. Variables for each category were determined to have the greatest correlation with MetS, and were used as independent variables in a step-wise, multiple linear regression to determine the best predictors for each MetS risk factor. Each variable was then ranked into tertiles and ANOVA/ANCOVA was performed with each MetS risk factor. Variables determined to have the greatest correlation with MetS were evaluated as covariates. A priori statistical significance was set at $p<0.05$.

Chapter 3
Manuscript

The Association between Sleep Quality, Physical Inactivity, and Risk of Developing Metabolic Syndrome

Abstract

Purpose The aim of this study is to assess the independent effects of sedentary time, sleep quality, and physical activity on risk factors for Metabolic Syndrome (MetS) in college students.

Methods 40 college aged students were recruited from James Madison University. Height, weight, blood pressure, waist circumference, and body composition were assessed on visit 1. Blood pressure, blood glucose, and lipid profile were assessed on visit 2. Subjects were required to wear an Actigraph GT3x accelerometer, which measured physical activity, sedentary time, and sleep quality for 7 days and nights. Univariate Pearson correlation analyses were performed to determine the relationship between sedentary, sleep quality, and physical activity variables with MetS risk factors. Variables for each category were determined to have the greatest correlation with MetS, and were used as independent variables in a step-wise, multiple linear regression to determine the best predictors for each MetS risk factor. Each variable was then ranked into tertiles and ANOVA/ANCOVA was performed with each MetS risk factor. Variables determined to have the greatest correlation with MetS were evaluated as covariates. A priori statistical significance was set at $p<0.05$.

Results Correlation analyses indicated the strongest predictors of MetS to be time per sedentary bout, time per awakening, step counts, and MVPA. Step counts and time per sedentary bouts were significant predictors of waist circumference ($R^2= .406$; $p<0.01$).

Step Counts and time per awakening were significant predictors of systolic blood pressure (R^2 = 0.49; p<0.01) and total MetS risk factors (R^2= 0.278; p=.002). Step counts was the only significant predictor of HDL (R^2=0.132; p=0.025). Waist circumference was greater in the lowest time per sedentary bout Tertile (83.04 ±11.3) compared to the highest Tertile (72.1 ±8.5). Systolic blood pressure was greater in the highest time per awakening tertile (124.4 ±12.3) compared to the lowest Tertile (111.8 ±10.2). Blood glucose was greater in the moderate time per awakening Tertile (84.4 ±6.9) compared to the lowest Tertile (77 ±7.4). Waist circumference was greater in the lowest time spent in MVPA Tertile (87.03 ±11.1) compared to the moderate (76.3 ±7.1) and highest Tertiles (71.9 ±9.3). Systolic blood pressure was greater in the lowest and moderate tertiles of time spent in MVPA Tertiles (125.5 ±12.6 and 121.7 ±8.6, respectively) compared to the highest Tertile (110.6 ±7.6). HDL was greater in the highest tertile of time spent in MVPA (68.6 ±13.1) compared to the moderate Tertile (60.4 ±9.4).

Conclusion Daily step counts and increased time spent in MVPA has the largest influence on preventing MetS and its respective risk factors in college students.

Introduction

To achieve health benefits from physical activity (PA) it is recommended that Americans accumulate 150 minutes a week of moderate-intensity aerobic activity, 75 minutes per week of vigorous intensity exercise, or a combination of the two (2, 8). However, in 2014, only 48% of Americans met these guidelines (11). Achieving this amount of PA has been shown to decrease the morbidity and mortality rates from various conditions, including cardiovascular disease (CVD), diabetes, obesity, hypertension, hyperlipidemia, as well as Metabolic Syndrome (MetS) (10, 39, 56). MetS is a cluster of interrelated CVD risk factors that include abdominal obesity, elevated triglycerides, low High Density Lipoprotein (HDL), impaired fasting glucose, and elevated blood pressure (2). When found together, there is an increased risk of developing CVD. Despite the preponderance of evidence linking PA and physical fitness with improved health outcomes, emerging evidence has suggested that, independent of PA, the amount of time spent sedentary may have a significant deleterious effect on health. On average, Americans spend 54.9%, or 7.7 hours, of their day sedentary (34). Even if an individual were to meet the guidelines previously mentioned, there is still an extensive amount of time in the day in which sedentary behaviors can occur. Sedentary behaviors are classified as activities that involve an energy expenditure of 1.0-1.5 METS (16, 34, 52). Some evidence has associated increased sedentary time with MetS as well as poor individual factors of cardiometabolic health such as blood pressure, glucose metabolism, obesity, and lipid profile (16, 21, 24). These findings have been confirmed independent of physical activity levels (12).

Sleep makes up approximately one third of an individual's life and over the past several decades, the diagnosis of sleep disorders and disturbances has risen sharply (32). The overall prevalence of disturbed sleep within the general population is between 35% and 41% (46). Sleep quality is measured by evaluating the sleep variables, sleep latency, sleep fragmentation, total sleep duration, and sleep efficiency (3, 31, 33, 41, 47, 51). There is a significant amount of evidence indicating a u-shaped relationship with sleep duration and poor cardiometabolic health (5, 9, 25, 29). Sleeping less than 6 hours per night or greater than 8 hours per night has been associated with increased risk of CVD mortality, diabetes, obesity, hypertension, dyslipidemia, as well as MetS (5, 9, 40, 42, 55). While few studies have examined these relationships with overall sleep quality, or each of its variables, some have shown an association with sleep quality and MetS using subjective measures such as questionnaires or surveys (17, 25). There is currently a lack of objective evidence assessing this relationship.

While this evidence suggests that physical inactivity and poor sleep quality will result in health detriments, these findings have primarily been seen in older populations. An important and understudied population in this area is younger adults or college students, although these individuals are at an increased risk for poor sleep quality, physical inactivity, and development of the MetS as a result of behavioral and lifestyle changes that occur when moving away from parental supervision. It is important to understand the potential causes of health risks in college students to prevent early mortality and morbidity.

To date, no published literature has objectively assessed whether physical inactivity or sleep quality in college students has a greater effect on MetS independent of

the other. Examining these relationships has the potential to shed light on the importance of sleep quality and limiting sedentary time in reducing the risk of developing MetS through the improvement of metabolic risk factors. Therefore, the purpose of this study is to objectively examine the association between sleep quality, sedentary time, and the risk of developing MetS in college students. It is hypothesized that physical inactivity will have a greater effect on MetS than sleep quality.

Methods

Study Design and Participants:

College aged students between the ages of 18 and 26 (n=40) were recruited through campus-wide emails, flyers, and word-of-mouth. Exclusion criteria of the study included individuals who have been diagnosed with cardiovascular, metabolic, or pulmonary disease. Participants were required to come to the James Madison University Kinesiology Human Performance Lab (HPL) on two separate occasions. All participants provided written informed consent and the protocol was approved by the James Madison University Institutional Review Board.

Visit 1

On the first visit, the first item that was read, discussed, and signed was the informed consent. Participants were then given a health history questionnaire, the Berlin questionnaire which assessed snoring characteristics(38), the Epworth Sleepiness Scale which determined level of daytime sleepiness(26), and the International Physical Activity Questionnaire Short Form (IPAQ) which assessed current physical activity patterns(13), to fill out. Blood pressure, body mass, height, and

waist circumference were then taken. Lastly, body composition was analyzed using a Dual Energy X-Ray Absorptiometer (DEXA). The DEXA scan provided total body fat percentage, total fat mass, total lean mass, fat free mass, estimated visceral fat mass, as well as estimated visceral fat volume. After all measures were taken, an Actigraph GT3X+ accelerometer (Actigraph, Pensacola, Florida) was programmed and instructions were provided to the subject on proper use. Participants were given one accelerometer to objectively record daily physical activity and sleep quality. Subjects wore the device for 7 consecutive days and nights. During the waking hours of the day, the accelerometer was worn on the participants' right hip to assess physical activity. During sleep, the accelerometer was worn on the non-dominant wrist. Participants were instructed to wear the device during all waking and sleep hours, only removing it when bathing or doing other water activities. Subjects were instructed to record time in bed and time out of bed on a provided log.

Visit 2

On visit 2, approximately 8 – 10 days after visit one, participants returned the accelerometer. A resting blood pressure was taken followed by a fasted blood sample via finger stick to assess for blood lipid values and blood glucose. Polymer Technology Systems lipid panel and glucose test strips were used in combination with a Cardiochek Portable Blood Test System to assess for the variables previously mentioned. After all assessments were completed, Framingham Risk Scores were calculated (54).

Measures:

Physical Activity. The Actigraph GT3X is a small activity monitor that measures accelerations throughout the day which are expressed as activity counts.

These activity counts were categorized as: sedentary, light activity, moderate activity, or vigorous activity using investigator-specified thresholds. Activity counts were summed over a 60 second epoch. The validity and reliability of the Actigraph GT3X accelerometers have been previously described (22, 27, 28, 43, 44). Once data is downloaded from the device, daily wear time was determined by removing periods of non-wear time defined as greater than 20 minutes of no detected movement. Blocks of time specified as sleep periods during the sleep analysis were also be treated as non-wear time. The data received could only be summarized if daily wear time was at least 10 hours. Daily average time spent in sedentary, light, moderate, vigorous, very vigorous, and moderate-vigorous physical activity (MVPA) intensities was determined. Average daily values were also determined in the following variables: energy expenditure, number of sedentary bouts, time in sedentary bouts, number of sedentary breaks, time of sedentary breaks, and step counts.

Sleep. The validity and reliability of using the Actigraph device as a measure of sleep quality has been previously described (3, 36, 48). Data collected by the accelerometer using a 60 second epoch was downloaded and analyzed by Actigraph software. To help determine certain sleep-wake variables, bedtime and wake time were recorded using a sleep diary. Average nightly values were determined for the following variables: sleep onset latency, sleep efficiency, time in bed, sleep time, wake after sleep onset, number of awakenings, and time per awakening.

Metabolic Syndrome. The Metabolic Syndrome was assessed using the ATP 3 criteria. To be diagnosed with the Metabolic Syndrome, an individual must meet at least three of the following criteria: Central Obesity (Waist Circumference >102cm in

men, >88cm in women); Hypertriglyceridemia (≥150mg/dL); Low HDL (<40 mg/dL in men, <50mg/dL in women); Elevated Blood Pressure (≥130/85mmHg); Elevated Fasting Glucose (≥110mg/dL) (2). Body composition and blood samples collected were utilized as previously described to assess for diagnosis.

Statistical Analyses

Univariate Pearson correlation analyses were performed to determine the relationship between sedentary, sleep quality, and physical activity variables with MetS risk factors. Variables for each category were determined to have the greatest correlation with MetS, and were used as independent variables in a step-wise, multiple linear regression to determine the best predictors for each MetS risk factor. Each variable was then ranked into tertiles and ANOVA/ANCOVA was performed with each MetS risk factor. Variables determined to have the greatest correlation with MetS were evaluated as covariates. A priori statistical significance was set at $p<0.05$.

Results

Forty participants (15 males, 25 females) had valid measures of objective physical activity, sedentary time, and sleep quality (Table 1). Out of the total sample, 1 subject was found to have MetS, therefore analyses were performed on individual MetS risk factors as well as estimated visceral fat. The number of MetS risk factors diagnosed per subject ranged from 0 to 4. Three subjects met the criteria for elevated waist circumference, 6 for elevated systolic blood pressure, 2 for elevated triglycerides, and 2 for low HDL. No subject had elevated fasted blood glucose.

Univariate Correlation Analysis

Univariate analysis results are presented in Table 2-4. The variables determined to have the strongest influence with MetS risk were average time per sedentary bout, average time per awakening, step counts, and average minutes of MVPA. Time per sedentary bout was correlated with waist circumference (Table 2). Time per awakening was correlated with systolic blood pressure (Table 3). MVPA was correlated with waist circumference and systolic blood pressure (Table 4). Step counts was correlated with waist circumference, systolic blood pressure, and HDL (Table 4).

Stepwise Linear Regression Analysis

The variables determined to have the strongest influence with MetS risk from correlation analysis were each used as independent variables to predict each MetS risk factor. Results yielded from stepwise linear regression analysis are presented in Table 5. Time per sedentary bout and step counts were the only significant predictors of waist circumference (R^2= .406; p<0.01). Step counts and time per awakening were the only significant predictors of systolic blood pressure (R^2 = 0.49; p<0.01) and total MetS risk factors (R^2= 0.278; p=.002). Step counts was the only significant predictor of HDL (R^2=0.132; p=0.025). No significant predictors were determined for blood glucose or triglycerides.

ANOVA/ANCOVA Analysis

The mean minutes ± standard deviations for time per sedentary bout Tertiles were 21.6 ± 1.02, 24.4 ± 0.9, and 28.7 ± 4.1 for the lowest, moderate, and highest, respectively. When examining by Tertile, waist circumference was significantly greater in the lowest time per sedentary bout Tertile (83.04 ±11.3) when compared to the highest (72.1 ±8.5) (p=0.03), even after controlling for average time per awakening, the only

significant covariate (p=0.014) (Figure 1). No other differences for waist circumference were noted between Tertiles. There were no other significant differences between time per sedentary bout Tertiles for other MetS variables.

The mean minutes ± standard deviations for time per awakening Tertiles were 2.4 ± 0.6, 3.2 ± 0.2, and 4.5 ± 1.0 for the lowest, moderate, and highest, respectively. When examining by Tertile, systolic blood pressure was significantly higher in the highest time per awakening Tertile (124.4 ±12.3) when compared to the lowest (111.8 ±10.2) (p=0.012), even after controlling for MVPA, the only significant covariate (p=0.001) (Figure 2A). No other differences for systolic blood pressure were noted between Tertiles. In addition, blood glucose was significantly higher in the moderate time per awakening Tertile (84.4 ±6.9) when compared to the lowest (77 ±7.4) (p=0.017) (Figure 2B). No significant covariates were found. No other differences for blood glucose were noted between Tertiles. There were no other significant differences between time per awakening Tertiles for other MetS variables.

The mean minutes ± standard deviations for MVPA Tertiles were 38.5 ± 5.3, 56.5 ± 5.9, and 92.2 ± 22 for the lowest, moderate, and highest, respectively. Waist circumference was significantly greater for the lowest time spent in MVPA Tertile (87.03 ±11.1) when compared to moderate time (76.3 ±7.1) (p=0.015) and the highest amount of time (71.9 ±9.3) (p=0.001) (Figure 3A), even after controlling for time per sedentary bout, the only significant covariate (p=0.005). No other differences for waist circumference were noted between Tertiles. Additionally, systolic blood pressure was significantly greater for the lowest time spent in MVPA Tertile (125.5 ±12.6) and moderate time (121.7 ±8.6), when compared to the highest time (110.6 ±7.6) (p=0.001;

p=0.017) (Figure 3B), even after controlling for time per awakening, the only significant covariate (*p*=0.004). No other differences for systolic blood pressure were noted between Tertiles. Use of oral contraception was found to be significantly correlated with HDL (mg/dL) (r= -.0414; p= 0.01), therefore ANCOVA was used with oral contraception as a covariate. After controlling for birth control, HDL was significantly higher for the highest time spent in MVPA Tertile (68.6 ±13.1) when compared to moderate time spent in MVPA (60.4 ±9.4) (Figure 3C). No other differences for HDL were noted between Tertiles. No other differences were found between MVPA Tertiles and MetS risk factors.

The mean ± standard deviations for step count Tertiles were 6571 ± 862, 9139 ± 1041, and 12639 ± 1392 for the lowest, moderate, and highest, respectively. Waist circumference was significantly higher for the lowest step count Tertile (84.6 ± 12.8) when compared to the highest step count Tertile (73.2 ± 11) (*p*=0.022), even after adjusting for time per sedentary bout, the only significant covariate (*p*=0.002). No other differences for waist circumference were noted between Tertiles. Systolic blood pressure was significantly higher for the lowest step count Tertile (127.8 ± 9.9) when compared to the moderate tertile (118.4 ± 9.7)(*p*=0.049) and the highest Tertile (112 ± 9.5)(*p*=0.001), even after adjusting for time per awakening, the only significant covariate (*p*=0.002). No other differences for systolic blood pressure were noted between Tertiles. HDL was significantly greater for the highest step count Tertile (68.5 ± 13.3) when compared to the lowest (54.5 ± 12.3)(*p*=0.021). Use of oral contraception was a significant covariate (*p*=0.002) but did not alter significance. No other differences for HDL were noted between Tertiles. No other differences were found between step count Tertiles and MetS risk factors.

Discussion

This study was conducted to determine whether sedentary time or sleep quality had a greater effect on risk of developing MetS in college students. Time per sedentary bout was found to have an inverse relationship with waist circumference while time per awakening was seen to have a positive relationship with systolic blood pressure, blood glucose, and total MetS risk factors. Results from the current study suggest, however, that physical activity levels may have the strongest influence on risk of developing MetS and its respective risk factors in college students.

Few studies have objectively examined the relationship between sleep quality and MetS. Data in the present study suggest that time per nightly awakening is a significant predictor of both systolic blood pressure and total MetS risk factors. Results indicated that increased time per nightly awakening was associated with an increase in systolic blood pressure and fasting blood glucose. This finding extends the results seen by Ekstedt, Akerstredt, & Soderstrom who examined the effects of arousals on metabolic dysregulation. Authors determined that an increased number of arousals (≥9) was associated with increased blood pressure, total cholesterol, LDL, and LDL/HDL in a sample of 24 participants with a mean age of 30 (17). Much like Ekstedt et al., our findings suggest that of all sleep quality variables, sleep fragmentation may have the largest effect on MetS risk. However, our findings indicate that time per awakening is of more significance than number of awakenings. The reason why time per nightly awakenings may have the greatest negative implications of sleep quality variables is unclear, however it is thought that it may be due to its effect on the sympathetic nervous system. Arousals from sleep have been associated with increased cortisol and

catecholamine secretion(17, 49, 50). Cortisol is known to stimulate lipolysis, while catecholamines are known to stimulate both lipolysis and gluconeogenesis as well as cause a rise in blood pressure.(4, 15, 19, 20). These known physiological responses match the results seen in the present study, supporting the theory that nightly awakenings has the greatest impact of all sleep quality variables on metabolic dysregulation.

Our observations indicate that time per sedentary bout was a significant predictor of waist circumference. Lower time per sedentary bout was associated with an increased waist circumference independent of sleep quality and MVPA. This was an unexpected finding and it contradicts studies assessing this relationship. Several studies have determined that increased sedentary time will be associated with more than one MetS risk factor and to be correlated with the prevalence of MetS (6, 14, 18, 21, 23). Healy et al. also specifically determined that independent of time spent in MVPA, there was a significant association between increased sedentary time and increased waist circumference in 169 participants with a mean age of 53.4. The physiological mechanisms of sedentary physiology causing MetS are not fully understood, however, there are several proposed mechanisms due to human bed rest studies and animal restricted movement studies. One theory is that sedentary time alters the phosphorlyation of Protein Kinase B and causes the reduction of GLUT-4 content, both leading to insulin resistance(6, 30, 35). Another is that both Lipoprotein Lipase and Hormone Sensitive Lipase activity will be reduced, resulting in hypertriglyceridemia or obesity and the negative effects associated with it (1, 6, 7). While this body of evidence provides a foundation for evaluating the physiological effects of physical inactivity, it exemplifies the most extreme form of physical inactivity rather than true daily sedentary time. A

majority of the evidence assessing sedentary time and MetS is performed in older adults. Due to the present findings only showing an inverse relationship between time per sedentary bout and waist circumference, it may be possible that the physiological mechanisms mentioned are not as prominent in younger adults or that sedentary time does not have the greatest influence on MetS risk in younger adults. This is supported by our findings involving physical activity levels.

A major finding of this study is that in young adults, daily step counts has the greatest influence on MetS risk when compared to sedentary time and sleep quality, which is contentious of our initial hypothesis. Step counts was found to be a significant predictor of waist circumference, systolic blood pressure, HDL, as well as total MetS risk factors. Low daily step counts was associated with an elevated waist circumference, elevated systolic blood pressure, as well as lower HDL level. These findings are supported by results found by Morrell et al. Authors specifically found that college students, with a similar age range to ours, who had the highest level of step counts per day had a lower prevalence of all MetS criteria when activity was measured via a pedometer (37). Our results also suggest that time spent in MVPA has an influence on MetS risk, although it was not found to be a significant predictor of any MetS risk factors. Greater time spent in MVPA was associated with a reduction of systolic blood pressure, reduction of blood glucose, as well as an increase in HDL. The benefits from participating in recommended levels of MVPA has been well documented across all age groups (53). Schilter and Dalleck determined that college students who self-reported higher levels of MVPA had higher HDL and lower fasting blood glucose (45). The sample of 203 men and women had a mean age of 20.3 years, which is near identical to

the present study. Our findings support this evidence, but are unique in that we have used a more objective and reliable technique to assess physical activity. To our knowledge, we are also the first to report that daily step counts and time spent in MVPA has a greater influence on MetS than sedentary time or sleep quality in young adults.

This study has several strengths, including the use of an objective, valid, and reliable measure of physical activity, sedentary time, and sleep quality. However, study limitations should be documented. First, our findings were determined in young adults(18-26), therefore, results cannot be generalized to other age groups. Second, only one subject was found to have MetS. Subjects were provided with extensive information about their health, therefore this sample could be skewed to individuals with greater interest in their health.

In conclusion, our findings highlight the importance of physical activity, sedentary time, and sleep quality to MetS risk in young adults. Our results suggest that daily step counts and meeting physical activity guidelines has the largest influence on preventing MetS and its respective risk factors in young college students.

Manuscript References

1. Alibegovic a C, Højbjerre L, Sonne MP, et al. Increased rate of whole body lipolysis before and after 9 days of bed rest in healthy young men born with low birth weight. *Am. J. Physiol. Endocrinol. Metab.* 2010;298:E555–64.

2. American College of Sports Medicine's Guidelines for Exercise Testing and Prescription9th ed. Baltimore, MD: Wolters Kluwer, Lippincott Williams & Wilkins; 2013.

3. Ancoli-Israel S, Cole R, Alessi C, Chambers M, Moorcroft W, Pollak CP. The role of actigraphy in the study of sleep and circadian rhythms. *Sleep* 2003;26(3):342–92.

4. Arner P. Human fat cell lipolysis: Biochemistry, regulation and clinical role. *Best Pract. Res. Clin. Endocrinol. Metab.* 2005;19(4):471–82.

5. Berg J, Knvistingh Neven A, Tulen JHM, et al. Actigraphic sleep duration and fragmentation are related to obesity in the elderly: the Rotterdam Study. *Int. J. Obes. (Lond).* 2008;32(7):1083–90.

6. Bergouignan a., Rudwill F, Simon C, Blanc S. Physical inactivity as the culprit of metabolic inflexibility: evidence from bed-rest studies. *J. Appl. Physiol.* 2011;111(August 2011):1201–10.

7. Bey L, Hamilton MT. Suppression of skeletal muscle lipoprotein lipase activity during physical inactivity: a molecular reason to maintain daily low-intensity activity. *J. Physiol.* 2003;551(Pt 2):673–82.

8. Buchner D. The Development and Content of the 2008 Physical Activity Guidelines for Americans. *JOPERD* 2014;13–6.

9. Buxton OM, Marcelli E. Short and long sleep are positively associated with obesity, diabetes, hypertension, and cardiovascular disease among adults in the United States. *Soc. Sci. Med.* 2010;71(5):1027–36.

10. Byberg L, Zethelius B, McKeigue PM, Lithell HO. Changes in physical activity are associated with changes in metabolic cardiovascular risk factors. *Diabetologia* 2001;44(12):2134–9.

11. Center for Disease Control: Physical Activity [Internet]2014;http://www.cdc.gov/physicalactivity/data/facts.htm.Available from: http://www.cdc.gov/physicalactivity/data/facts.htm

12. Chase JM, Lockhart CK, Madden KM. Accelerometer-based measures of sedentary behavior and cardio- metabolic risk in active older adults. 2014;37(2):108–17.

13. Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-Country reliability and validity. *Med. Sci. Sports Exerc.* 2003;35:1381–95.

14. Diabetes TA, Ausdiab LS. Objectively Measured Sedentary Time , Physical Activity , and Metabolic Risk. 2008;31(2)

15. Djurhuus CB, Gravholt CH, Nielsen S, et al. Effects of cortisol on lipolysis and regional interstitial glycerol levels in humans. *Am. J. Physiol. Endocrinol. Metab.* 2002;283:E172–7.

16. Edwardson CL, Gorely T, Davies MJ, et al. Association of sedentary behaviour with metabolic syndrome: a meta-analysis. *PLoS One* 2012;7(4):e34916.

17. Ekstedt M, Akerstedt T, Söderström M. Microarousals during sleep are associated with increased levels of lipids, cortisol, and blood pressure. *Psychosom. Med.* 2004;66(6):925–31.

18. Ford ES, Iii HWK, Mokdad AH, Ajani UA, Earl S, Ali H. Sedentary Behavior , Physical Activity , and the Metabolic Syndrome among U . S . Adults. 2005;13(3):608–14.

19. Glucagon OF, Perfused INTHE. Control of Gluconeogenesis in Liver. 1968;243(16):4189–96.

20. Goldstein DS. Plasma catecholamines and essential hypertension. An analytical review. *Hypertension* [date unknown];5:86–99.

21. Helmerhorst HJF, Wijndaele K, Brage S, Wareham NJ. Objectively Measured Sedentary Time May Predict Insulin Resistance Independent of Moderate- and Vigorous-Intensity Physical Activity. *Diabetes* 2009;58:1776–9.

22. Hendelman D, Miller K, Baggett C, Debold E, Freedson P. Validity of accelerometry for the assessment of moderate intensity physical activity in the field. *Med. Sci. Sports Exerc.* 2000;32:S442–9.

23. Henson J, Yates T, Biddle SJH, et al. Associations of objectively measured sedentary behaviour and physical activity with markers of cardiometabolic health. *Diabetologia* 2013;56:1012–20.

24. Hu FB, Li TY, Colditz GA. Television Watching and Other Sedentary Behaviors in Relation to Risk of Obesity and Type 2 Diabetes Mellitus in Women. *JAMA* 2014;289(14):1785–91.

25. Hung H-C, Yang Y-C, Ou H-Y, Wu J-S, Lu F-H, Chang C-J. The association between self-reported sleep quality and metabolic syndrome. *PLoS One* 2013;8(1):e54304.

26. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. *Sleep* 1991;14:540–5.

27. Kaminsky L a, Ozemek C. A comparison of the Actigraph GT1M and GT3X accelerometers under standardized and free-living conditions. *Physiol. Meas.* 2012;33(11):1869–76.

28. Kozey-Keadle S, Libertine A, Lyden K, Staudenmayer J, Freedson PS. Validation of wearable monitors for assessing sedentary behavior. *Med. Sci. Sports Exerc.* 2011;43(8):1561–7.

29. Kronholm E, Laatikainen T, Peltonen M, Sippola R, Partonen T. Self-reported sleep duration, all-cause mortality, cardiovascular mortality and morbidity in Finland. *Sleep Med.* 2011;12(3):215–21.

30. Kump DS, Booth FW. Alterations in insulin receptor signalling in the rat epitrochlearis muscle upon cessation of voluntary exercise. *J. Physiol.* 2005;562:829–38.

31. Kushida C a, Chang a, Gadkary C, Guilleminault C, Carrillo O, Dement WC. Comparison of actigraphic, polysomnographic, and subjective assessment of sleep parameters in sleep-disordered patients. *Sleep Med.* 2001;2(5):389–96.

32. Lauderdale DS, Knutson KL, Yan LL, et al. Objectively measured sleep characteristics among early-middle-aged adults: the CARDIA study. *Am. J. Epidemiol.* 2006;164(1):5–16.

33. Lockley SW, Skene DJ, Arendt J. Comparison between subjective and actigraphic measurement of sleep and sleep rhythms. *J. Sleep Res.* 1999;8(3):175–83.

34. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the United States, 2003-2004. *Am. J. Epidemiol.* 2008;167(7):875–81.

35. Megeney LA, Elder GCB, Bonen A, Blewett CA, Effects AB. Effects of muscle activity and fiber composition on glucose transport and GLUT-4. 1993;E583–92.

36. Morgenthaler T, Alessi C, Friedman L, et al. Practice parameters for the use of actigraphy in the assessment of sleep and sleep disorders: an update for 2007. *Sleep* 2007;30(4):519–29.

37. Morrell JS, Cook SB, Carey GB. Cardiovascular fitness, activity, and metabolic syndrome among college men and women. *Metab. Syndr. Relat. Disord.* 2013;11(5):370–6.

38. Netzer NC, Stoohs R a., Netzer CM, Clark K, Strohl KP. Using the Berlin Questionnaire to identify patients at risk for the sleep apnea syndrome. *Ann. Intern. Med.* 1999;131(7):485–91.

39. Paffenbarger R, Hyde R, Wing A, Hsieh C. Physical Activity, All-Cause Mortality, and Longevity of College Men. *N. Engl. J. Med.* 1986;314(10):605–13.

40. Sabanayagam C, Shankar A. Sleep duration and cardiovascular disease: results from the National Health Interview Survey. *Sleep* 2010;33(8):1037–42.

41. Sadeh A, Hauri J, Kripke DF. An American Sleep Disorders Association Review The Role of Actigraphy in the Evaluation of Sleep Disorders. *Sleep* 1995;18(4):288–302.

42. Saleh D, Janssen I. Interrelationships among sedentary time, sleep duration, and the metabolic syndrome in adults. *BMC Public Health* 2014;14(1):666.

43. Santos-Lozano a, Santín-Medeiros F, Cardon G, et al. Actigraph GT3X: Validation and Determination of Physical Activity Intensity Cut Points. *Int. J. Sports Med.* 2013;34(11):975–82.

44. Sasaki JE, John D, Freedson PS. Validation and comparison of ActiGraph activity monitors. *J. Sci. Med. Sport* 2011;14(5):411–6.

45. Schilter J, Dalleck L. Fitness and Fatness: Indicators of Metabolic Syndrome and Cardiovascular Disease Risk Factors in College Students? *J. Exerc. Physiol.* 2010;13(4):29–40.

46. Sherrill DL, Kotchou K, Quan SF. Association of Physical Activity and Human Sleep Disorders. *ARCH INTERN MED* 1998;158:1894–8.

47. Silva G, Goodwin J, Sherrill D, et al. Relationship Between Reported and Measured Sleep Times :The Sleep Heart Health Study (SHHS). *J. Clin. Sleep Med.* 2007;3(6):622–30.

48. Souza L De, Benedito-silva AA, Laura M, et al. Further Validation of Actigraphy for Sleep Studies. *Sleep* 2003;26(1):81–5.

49. Spath-Schwalbe E, Gofferje M, Kern W, Born J, Fehm HL. Sleep disruption alters nocturnal ACTH and cortisol secretory patterns. *Biol. Psychiatry* 1991;29:575–84.

50. Spiegel K, Leproult R, Van Cauter E. Impact of sleep debt on metabolic and endocrine function. *Lancet* 1999;354:1435–9.

51. Tonetti L, Pasquini F, Fabbri M, Belluzzi M, Natale V. Comparison of two different actigraphs with polysomnography in healthy young subjects. *Chronobiol. Int.* 2008;25(1):145–53.

52. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Appl. Physiol. Nutr. Metab.* 2010;35(6):725–40.

53. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence. *CMAJ* 2006;174(6):801–9.

54. Wilson W, Castelli W, Kannel W. Coronary Risk Prediction in Adults (The Framingham Heart Study). *Am. J. Cardiol.* 1987;59:91G – 94G.

55. Yaggi HK, Araujo AB, McKinlay JB. Sleep duration as a risk factor for the development of type 2 diabetes. *Diabetes Care* 2006;29(3):657–61.

56. Yang X, Telama R, Hirvensalo M, Mattsson N, Viikari JS a, Raitakari OT. The longitudinal effects of physical activity history on metabolic syndrome. *Med. Sci. Sports Exerc.* 2008;40(8):1424–31.

Table 1. Descriptive characteristics of study participants (n=40)

Variable	Mean (SD)
Age (yr.)	20.2 (1.7)
BMI (kg/m^2)	21.2 (2.6)
Waist Circumference (cm)	71 (6.6)
Percent Body Fat (%)	24.3 (6.7)
Average Systolic Blood Pressure (mmHg)	115.9 (10.2)
Average Diastolic Blood Pressure (mmHg)	73.2 (7.2)
Blood Glucose (mg/dL)	78.9 (4.4)
Triglycerides (mg/dL)	87.3 (28.2)
Low-Density Lipoprotein (mg/dL)	74.7 (30.2)
High-Density Lipoprotein (mg/dL)	63.8 (7.8)
Total Cholesterol (mg/dL)	155.8 (32.5)
Total Cholesterol/HDL	2.5 (0.6)
Sedentary Variables	
Sedentary Bouts per Day	19.0 (3.6)
Time in Sedentary Bouts per Day (min)	504.5 (91.2)
Time per Sedentary Bout (min)	27.4 (4.7)
Time in Sedentary Breaks per Day (min)	940.1 (91.6)
Time per Sedentary Break (min)	55.7 (21)
Sedentary Activity Minutes per Day (min)	688.2 (89.4)
Sleep Quality Variables	
Sleep Latency per Night (min)	5.8 (2.7)
Sleep Efficiency per Night (%)	84.8 (5.5)
Time in Bed per Night (min)	461.7 (60.4)
Sleep Time per Night (min)	389.7 (61.6)
Wake After Sleep Onset per Night (min)	66.1 (25)
Number of Awakenings per Night	20.5 (7)
Time per Awakening per Night (min)	3.2 (1.2)
Physical Activity Variables	
Light Activity Minutes per Day (min)	152.3 (32.4)
Moderate Activity Minutes per Day (min)	65 (27.1)
Vigorous Activity Minutes per Day (min)	7.3 (11.4)
Very Vigorous Activity Minutes per Day (min)	0.15 (0.3)
Moderate-Vigorous Activity Minutes per Day (min)	72.5 (30)
Steps per Day	10313.5 (2512.8)
Daily Energy Expenditure (kcals)	492.5 (50)

Table 2. Initial Correlations between Sedentary Variables and Metabolic Syndrome Risk Factors

	Sedentary Bouts per Day	Time in Sedentary Bouts per Day	Time per Sedentary Bout	Time in Sedentary Breaks per Day	Time per Sedentary Break	Sedentary Activity Minutes per Day
Waist Circumference	-0.16	-0.42**	-0.5**	0.35*	0.18	-0.35*
Systolic Blood Pressure	0.03	-0.03	-0.12	0.01	-0.03	-0.02
Blood Glucose	-0.10	-0.10	-0.12	0.10	0.08	-0.13
HDL	-0.01	0.10	0.25	-0.02	0.01	-0.05
Triglycerides	0.02	-0.04	0.01	0.03	-0.08	-0.00

* **p < 0.05**

** **p < 0.01**

Table 3. Initial Correlations between Sleep Quality Variables and Metabolic Syndrome Risk Factors

	Sleep Latency	Sleep Efficiency	Time in Bed	Sleep Time	Wake After Sleep Onset	Number of Awakenings	Time per Awakening
Waist Circumference	0.14	-0.10	-0.20	-0.21	-0.03	-0.27	0.30
Systolic Blood Pressure	0.21	-0.10	-0.10	-0.14	0.04	-0.30	0.48**
Blood Glucose	0.13	-0.06	-0.12	-0.12	-0.04	-0.24	0.29
HDL	0.12	0.06	0.12	0.16	-0.11	0.11	-0.34*
Triglycerides	0.22	-0.02	0.15	0.11	0.06	-0.08	0.13

* **$p < 0.05$**

** **$p < 0.01$**

Table 4. Initial Correlations between Physical Activity Variables and Metabolic Syndrome Risk Factors

	Light Activity Minutes	Moderate Activity Minutes	Vigorous Activity minutes	Very Vigorous Activity Minutes	MVPA	Steps Count
Waist Circumference	0.35*	-0.37*	-0.11	-0.09	-0.36*	-0.46**
Systolic Blood Pressure	0.04	-0.49**	-0.07	-0.28	-0.46**	-0.56**
Blood Glucose	0.12	0.12	-0.13	-0.07	0.07	0.02
HDL	-0.03	0.28	0.05	0.20	0.26	0.36*
Triglycerides	-0.02	-0.16	-0.09	-0.31	-0.18	-0.17

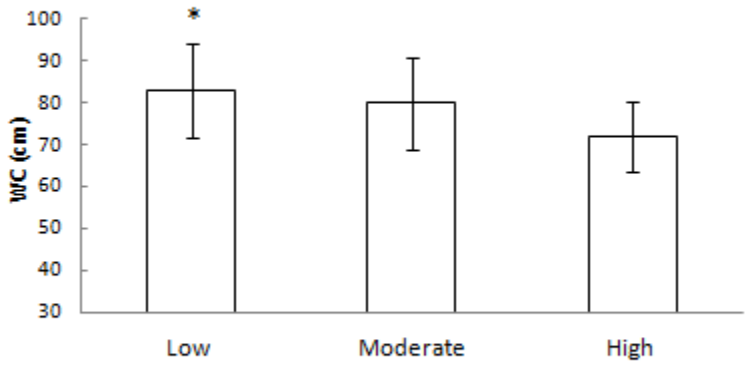
* **$p < 0.05$**

** **$p < 0.01$**

Table 5. Predictive Value of Sleep Quality, Physical Inactivity, and Physical Activity Variables on MetS Risk Factors

	β	*p* value
Waist Circumference(cm)		
Time per Sedentary Bout	-1.3	0.001
Step Counts	-0.002	0.004
Systolic Blood Pressure(mmHg)		
Step Counts	-0.002	<0.001
Time per Awakening	4.38	0.001
HDL(mg/dL)		
Step Counts	0.002	0.025
Total MetS Risk Factors		
Time per Awakening	0.25	0.013
Step Counts	-0.0001	0.02

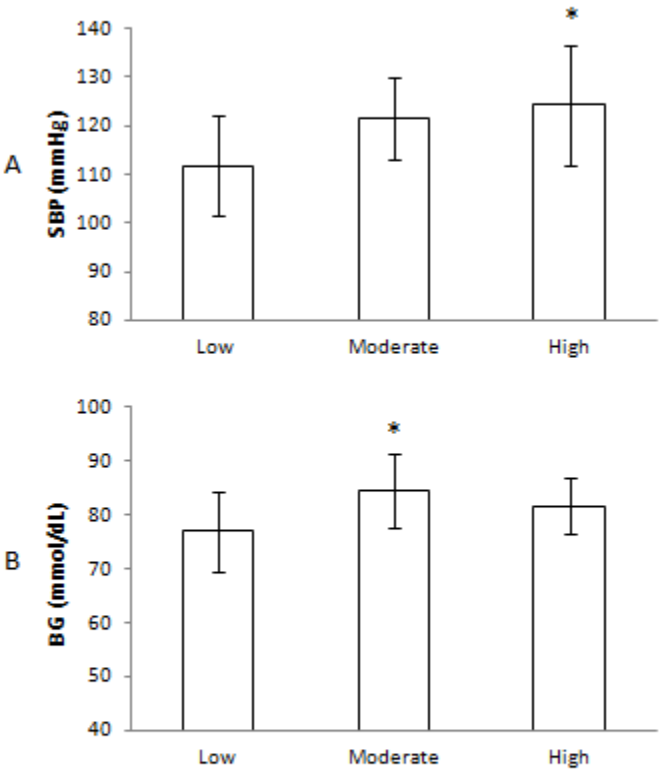
Figure 1. The Effect of Average Time per Sedentary Bout Tertiles on Waist Circumference



Means ± Standard Deviations

*Low time per sedentary bout is greater than high time per sedentary bout($p<0.05$)

Figure 2. The Effect of Average Time per Awakening Tertiles on Systolic Blood Pressure and Blood Glucose



Means ± Standard Deviations

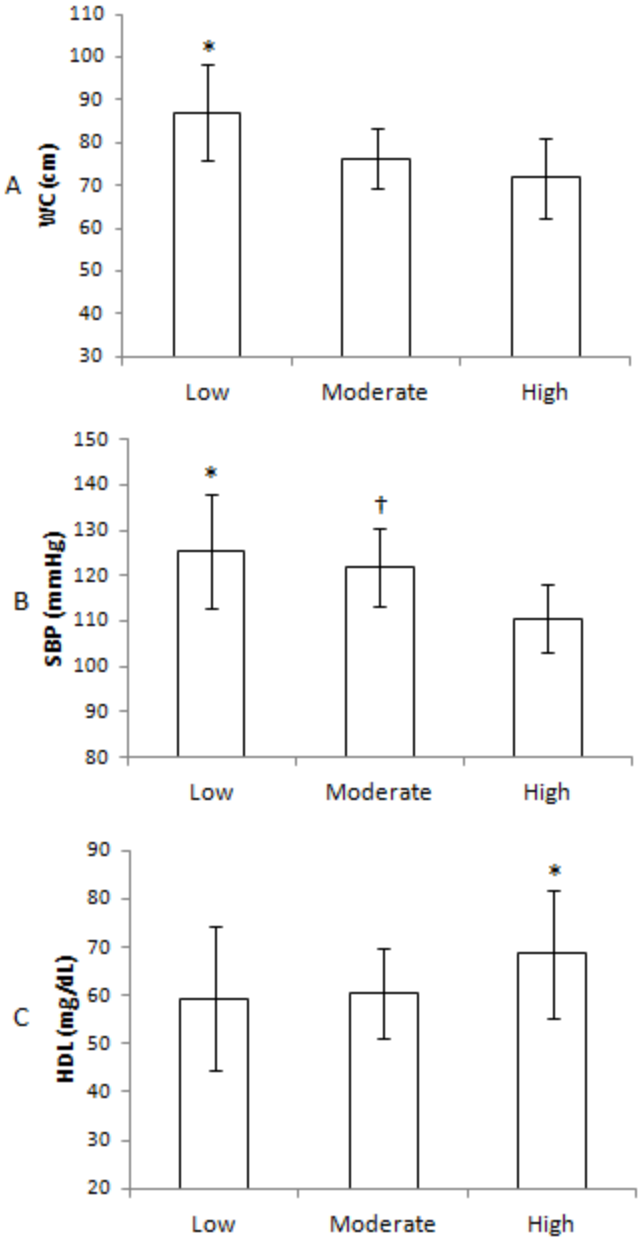
A. Systolic Blood Pressure;

*High time per awakening is greater than low time per awakening ($p<0.05$)

B. Blood Glucose;

*Moderate time per awakening is greater than low time per awakening ($p<0.05$)

Figure 3. The Effect of MVPA Tertiles on Waist Circumference, Systolic Blood Pressure, and HDL



Means ± Standard Deviations

A. Waist Circumference;

* Low MVPA is greater than moderate ($p<0.05$) & high MVPA($p<0.01$)

B. Systolic Blood Pressure;

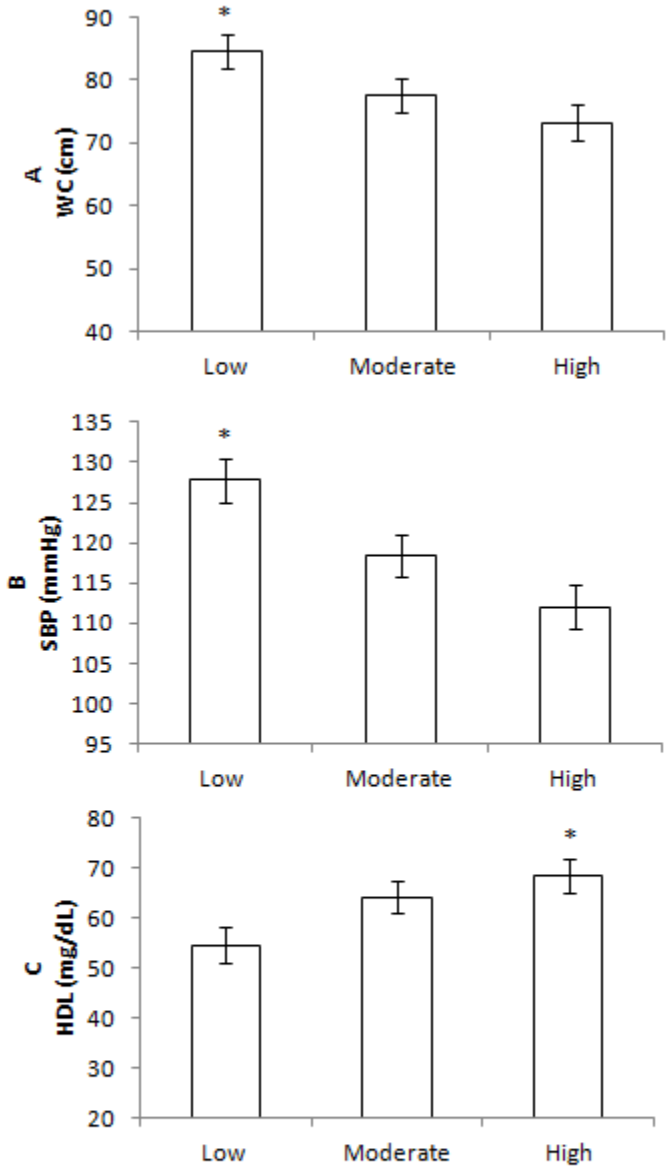
* Low MVPA is greater than high MVPA ($p<0.01$)

† Moderate MVPA is greater than high MVPA ($p<0.05$)

C. HDL (Adjusted for Birth Control)

* High MVPA is greater than moderate MVPA ($p<0.05$)

Figure 4. The Effect of Average Step Count Tertiles on Waist Circumference, Systolic Blood Pressure, and HDL.



Means ± Standard Deviations

A. Waist Circumference

*Low step counts is greater than high step counts ($p<0.05$)

B. Systolic Blood Pressure

*Low step counts is greater than moderate ($p<0.05$) and high step counts ($p<0.01$)

C. HDL

*High step counts is greater than low step counts ($p<0.05$)

Appendix A:

Informed Consent

James Madison University
Department of Kinesiology
Informed Consent

Purpose

You are being asked to volunteer for a research project conducted by Dr. Trent Hargens from James Madison University entitled, “The Association Between Sleep Quality, Physical Inactivity, and Risk of Developing the Metabolic Syndrome".

The primary goal of this study is to examine whether sleep quality and/or physical activity amount impacts the risk of developing the Metabolic Syndrome. This may provide a clearer picture into which factors have a stronger influence in the possible development of the Metabolic Syndrome.

The Metabolic Syndrome is the name for a group of risk factors that raises your risk for heart disease and other health problems, such as diabetes and stroke. Those risk factors include:

- Abdominal Obesity
- Elevated Triglycerides
- Low HDL
- Impaired Fasting Glucose
- Elevated Blood Pressure

Experimental Procedures

You will be asked to visit the Human Performance Laboratory (HPL) in Godwin Hall 2 times over the course of about 7 – 10 days. For visit two, you will need to be fasted for at least 8-12 hours. Your total time commitment for participation in this study will be approximately 2 hours. You will be asked to wear a device (an accelerometer) on your waist during the day for a period of 7 days, while wearing the same device on your wrist at night while you sleep. Detailed information on each visit is provided below:

Visit 1

Before any test is given, you will be asked to complete a screening form and an informed consent, to insure that you meet the study criteria, that you do not have any factors that would disqualify you from participation. Upon completion of the informed consent, you will be asked to complete a short health history questionnaire providing information about your characteristics and health. You will then be asked complete 3 standardized questionnaires about snoring, your physical activity patterns, and risk for cardiovascular disease.

You will then have your blood pressure, height, weight, and waist circumference measured. After that, your body composition will be analyzed via a Dual-energy x-ray absorptiometer (DEXA). The DEXA scan will allow us to measure your percent body fat. The DEXA is much like an X-ray machine. The DEXA will scan your entire body very slowly; so, you will need to lie on a table without moving for almost 10 minutes, while the DEXA is passed over your entire body. You will feel no discomfort associated with this test. At the end of this first visit you will also be given instructions on wearing the accelerometer. An accelerometer is a small device that is to be worn on your waist during the day and on your wrist while in bed.

Visit 2

Approximately 7-10 days after Visit 1, you will be asked to return to the HPL for your final visit. For this visit, you will need to be fasted for 8-12 hours. This means that you cannot eat or drink anything, expect for plain water, for 8-12 hours prior to coming into the lab. During this visit you will also return the accelerometers and have your blood pressure measured. Lastly, a finger stick will be performed to collect two small samples of blood. These blood samples will be used to determine your blood lipid and glucose levels.

Risks

There are no risks associated with wearing an accelerometer. Also, there is no risk associated with heart rate, blood pressure, height, weight, and waist circumference measures. You will not be asked to change any of your personal habits during the course of the study. Measurements with associated risks include: the DEXA scan.

The amount of radiation that you will receive in the DEXA exam is less than the amount you will receive during a transatlantic flight, and is equal to about 1/20 of a chest x-ray. If you are female, you should not be pregnant for this study because of risks from the DEXA scan radiation to the embryo or fetus. If you feel that you might be pregnant, inform the research staff immediately.

Benefits

Participation may include knowledge about your health status. You will receive information on your body composition, including percent body fat and bone mineral density, an assessment of your blood lipid and glucose levels, an assessment of your sleep quality, and an assessment of your physical activity level. Indirect benefits of participating in this study will be helping the researchers better understand the relationship between sleep quality, physical inactivity, and the Metabolic Syndrome.

Inquiries

If you have any questions or concerns or you would like to receive a copy of the final aggregate results of this study, please contact Dr. Trent Hargens at hargenta@jmu.edu or (540) 568-5844.

Questions about Your Rights as a Research Subject

Dr. David Cockley
Chair, Institutional Review Board
James Madison University
(540) 568-2834
cocklede@jmu.edu

Confidentiality

All data and results will be kept confidential. You will be assigned an identification code. At no time will your name be identified with your individual data. The researcher retains the right to use and publish non-identifiable data. All data will be kept secured in a locked cabinet. All electronic data will be kept on a password-protected computer. Final aggregate results will be made available to participants upon request.

Freedom of Consent

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind.

I have read this consent form and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

_____	_____
Name of Subject (Printed)	Name of Researcher (Printed)
_____	_____
Name of Subject (Signed)	Name of Researcher (Signed)
_____	_____
Date	Date

Appendix B:

Medical and Health History Form

Medical and Health History Form

Name: _____ Date of Birth: _____

Ethnicity: _____

Height: _____ ft Weight: _____ pounds

Gender: Female_____ Male_____

Campus Address: _____

Campus Telephone Number: _____ Campus Email Address: _____

Address for Permanent Residence: _____

Person to contact in case of emergency: _____

Relationship: _____ Daytime Telephone: _____ Home Telephone: _____

Primary Care Physician: _____ Telephone: _____

Medical History

Please indicate any current or previous conditions or problems you have experienced or have been told by a physician you have had:

	Yes	**No**
Heart disease or any heart problems:	_____	_____
Rheumatic fever:	_____	_____
Respiratory disease or breathing problems:	_____	_____
Circulation problems:	_____	_____
Kidney disease or problems:	_____	_____
Urinary problems:	_____	_____
Reproductive problems:	_____	_____
Musculoskeletal problems:	_____	_____
Fainting or dizziness, especially with exertion:	_____	_____
Neurological problems/disorders:	_____	_____
High blood pressure:	_____	_____
Low blood pressure:	_____	_____
High blood cholesterol:	_____	_____
Diabetes:	_____	_____

Thyroid problems:	_____	_____
Eating disorders (bulimia, anorexia):	_____	_____
Allergies:	_____	_____

If "yes" to any of the above please indicate the date, explain, and describe:

_____

_____

_____

Please list any hospitalizations/operations/recent illnesses (Type/Date):_____

_____

_____

_____

Do you ever feel faint, short of breath, or chest discomfort with exertion? Yes: _____ No: _____

If "yes", please explain : _____

_____

Are there any orthopedic limitations you have that may restrict your ability to perform hard running exercise or intense strength-type exercises? (back, hips, knees, ankles) Yes _____ No _____

If "yes" please explain: _____

_____

_____

_____

Family Health History

Has anyone in your family (blood relatives only) been diagnosed or treated for any of the following?

	Yes	**No**	**Relationship**	**Age**
Heart attack	_____	_____	_____	_____
Heart disease	_____	_____	_____	_____
High blood pressure	_____	_____	_____	_____
Stroke	_____	_____	_____	_____
Kidney disease	_____	_____	_____	_____
Diabetes	_____	_____	_____	_____

Health Habits

Do you add salt to your food? Yes ___ No ___ Are you on any special type of diet? Yes ___ No ___

If "yes" please describe _____

_____

Do you drink caffeinated beverages? Yes _____ No _____ How many cups per day? _____

Do you drink alcoholic beverages? Yes _____ No _____ How many drinks per week? _____

What is the average number of drinks that you consume on the weekend? _____

Did you use tobacco products in the past (more than 12 months ago)? Yes _____ No _____

Sleep Habits Evaluation

Do you have episodes of parasomnias (disorders such as sleep walking, sleep talking, night terrors, body rocking, bedwetting that will cause partial or full awakening?) Yes_____ No_____

Do you show signs of sleep disturbances (such as insomnia, daytime sleepiness) when you are anxious, stressed? Yes_____ No_____

Do you have difficulties to fall asleep if a certain object or a certain situation is absent such as listening to the radio, watching the television, etc? Yes_____ No_____

Do you have difficulties to fall asleep earlier or later of your usual bedtime? Yes_____ No___ _____

Do you wake up at night to get a little snack? Yes_____ No_____

If “yes”, do you think that the snack is helping you to go back to sleep? Yes_____ No_____

Do you have hallucinations (vivid images that look like dreams occurring when you sleep) or find yourself physically weak or paralyzed for a few seconds? Yes_____ No_____ _____

<u>Tonsils and Adenoids evaluation questionnaire</u>

Do you have a history of recurrent tonsillitis which is an inflammation of the tonsils (clusters of tissue that lie in bands on both sides of the back of the throat) caused by an infection? In tonsillitis, the tonsils are enlarged, red, and often coated either partly or entirely? Yes_____ No_____

Did you ever have inflammation of the adenoids (single clump of tissue in the back of the nose) causing a blockage of the back of the nose, chronic and recurrent fluid or infections of your ears, or chronic or recurrent sinus infections? Yes_ No_____

Did you have tonsillectomy (tonsils removed) or adenoidectomy (adenoids removed)? Yes_____ No_____

Medications

Please list all medications (prescription and over-the-counter) you are currently taking or have taken in the past week: _____

_____

_____

_____

_____

_____

_____

_____

Please sign to indicate the above information is correct:

_____ _____

Print Name Signature Date

Follow Up Review and Interview by: _____

Signature of Project Staff Member Date

Appendix C:

Epworth Sleepiness Scale

Epworth Sleepiness Scale

Subject ID_____ Date Completed ____/____/____

This questionnaire asks you to indicate the chances of you becoming drowsy during hours of the day that you are not in bed sleeping. "How likely are you to doze off or fall asleep in the following situations?"

Use the following scale and indicate the most appropriate number for each situation.

0 = would never doze
1 = slight chance of dozing
2 = moderate chance of dozing
3 = high chance of dozing

	Situation	**Chance of Dozing**
1.	Sitting and reading	_____
2.	Watching T.V.	_____
3.	Sitting, inactive in a public place (ex. Theatre or meeting)	_____
4.	As a passenger in a car for an hour without a break	_____
5.	Lying down to rest in the afternoon when circumstances permit	_____
6.	Sitting and talking with someone	_____
7.	Sitting quietly after a lunch without alcohol	_____
8.	In a car, while stopped for a few minutes in the traffic	_____

Sum of Scores, items 1-8 (staff use only) **_____/24**

Appendix D:

Berlin Questionnaire

Berlin Questionnaire

Subject ID_____ Date Completed ____/____/____

Height (cm) _____Weight (kg) _____ Age _____

Please choose the correct response to each question.

Category 1

1. **Do You Snore?**
   - ☐ a. Yes
   - ☐ b. No
   - ☐ c. Don't know

If you snore:

2. **Your snoring is:**
   - ☐ a. Slightly louder than breathing
   - ☐ b. As loud as talking
   - ☐ c. Louder than talking
   - ☐ d. Very loud – can be heard in adjacent rooms

3. **How often do you snore?**
   - ☐ a. Nearly every day
   - ☐ b. 3-4 times a week
   - ☐ c. 1-2 times a week
   - ☐ d. 1-2 times a month
   - ☐ e. Never or nearly never

4. **Has your snoring every bothered other people?**
   - ☐ a. Yes
   - ☐ b. No
   - ☐ c. Don't Know

5. **Has anyone noticed that you quit Breathing during your sleep?**
   - ☐ a. Nearly every day
   - ☐ b. 3-4 times a week
   - ☐ c. 1-2 times a week

☐ d. 1-2 times a month
☐ e. Never or nearly never

Category 2

6. **How often do you feel tired or fatigued after you sleep?**
☐ a. Nearly every day
☐ b. 3-4 times a week
☐ c. 1-2 times a week
☐ d. 1-2 times a month
☐ e. Never or nearly never

7. During your waking time, do you feel tired, fatigued or not up to par?
☐ a. Nearly every day
☐ b. 3-4 times a week
☐ c. 1-2 times a week
☐ d. 1-2 times a month
☐ e. Never or nearly never

8. Have you ever nodded off or fallen asleep while driving a vehicle?
☐ a. Yes
☐ b. No

If yes:

9. How often does this occur?
☐ a. Nearly every day
☐ b. 3-4 times a week
☐ c. 1-2 times a week
☐ d. 1-2 times a month
☐ e. Never or nearly never

Category 3

10. **Do you have high blood pressure?**
☐ a. Yes
☐ b. No
☐ c. Don't Know

Appendix E:

International Physical Activity Questionnaire Short Form (IPAQ-SF)

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ **days per week**

   ☐ No vigorous physical activities → ***Skip to question 3***

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

   _____ **hours per day**

   _____ **minutes per day**

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   _____ **days per week**

   ☐ No moderate physical activities → ***Skip to question 5***

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

_____ hours per day

_____ minutes per day

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ days per week

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ hours per day

_____ minutes per day

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ hours per day

_____ minutes per day

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

Appendix F:

Physical Activity Monitor Instructions & Log

Physical Activity Monitor Instructions & Log

- Please do your normal activities while wearing the monitor. Try to refrain from intentionally increasing your physical activity beyond what you "normally" do while wearing the monitor.
- During normal waking hours the monitor should be placed on your belt or waistband at the midline of the thigh (If you wear a belt, clips the monitor to the belt, otherwise just clip it to your waistband).
- At night while in bed, the monitor should be worn on the wrist of your non-dominant arm.
- The monitor should be worn at all times except when swimming or showering.
- Thank you for participating in this research study

_____
Name

Mon Night Date:	Tues Night Date:	Wed Night Date:	Thurs Night Date:	Fri Night Date:	Sat Night Date:	Sun Night Date:
Time in bed: _____	Time in bed: _____	Time in bed: _____	Time in bed: _____	Time in bed: _____	Time in bed: _____	Time in bed: _____
Time out of bed: _____	Time out of bed: _____	Time out of bed: _____	Time out of bed: _____	Time out of bed: _____	Time out of bed: _____	Time out of bed: _____

Please report if you did not have the monitor on for the whole day (list day, reason, and how long it was not on). If none, check here _____.

Please report any days you performed a planned bout of exercise (list day, type of exercise, and how long you performed the activity). If none, check here _____.

Please report any days you performed activities that did not require a lot of moving around, but rather more arm activities (list day, type of activity, and how long you performed the activity). If none, check here ____.

Comment on any unusual or atypical physical activities (activities that you do not usually participate in on a regular basis) you performed during the past week. If none, check here _____.

References:

1. Alibegovic a C, Højbjerre L, Sonne MP, et al. Increased rate of whole body lipolysis before and after 9 days of bed rest in healthy young men born with low birth weight. *Am. J. Physiol. Endocrinol. Metab.* 2010;298:E555–64.

2. American College of Sports Medicine's Guidelines for Exercise Testing and Prescription9th ed. Baltimore, MD: Wolters Kluwer, Lippincott Williams & Wilkins; 2013.

3. Ancoli-Israel S, Cole R, Alessi C, Chambers M, Moorcroft W, Pollak CP. The role of actigraphy in the study of sleep and circadian rhythms. *Sleep* 2003;26(3):342–92.

4. Bankoski A, Harris TB, McClain JJ, et al. Sedentary activity associated with metabolic syndrome independent of physical activity. *Diabetes Care* 2011;34(2):497–503.

5. Beltrán-Sánchez H, Harhay MO, Harhay MM, McElligott S. Prevalence and trends of metabolic syndrome in the adult U.S. population, 1999-2010. *J. Am. Coll. Cardiol.* 2013;62(8):697–703.

6. Berg J, Knvistingh Neven A, Tulen JHM, et al. Actigraphic sleep duration and fragmentation are related to obesity in the elderly: the Rotterdam Study. *Int. J. Obes. (Lond).* 2008;32(7):1083–90.

7. Bergouignan a., Rudwill F, Simon C, Blanc S. Physical inactivity as the culprit of metabolic inflexibility: evidence from bed-rest studies. *J. Appl. Physiol.* 2011;111(August 2011):1201–10.

8. Bey L, Hamilton MT. Suppression of skeletal muscle lipoprotein lipase activity during physical inactivity: a molecular reason to maintain daily low-intensity activity. *J. Physiol.* 2003;551(Pt 2):673–82.

9. Buchner D. The Development and Content of the 2008 Physical Activity Guidelines for Americans. *JOPERD* 2014;13–6.

10. Buxton OM, Marcelli E. Short and long sleep are positively associated with obesity, diabetes, hypertension, and cardiovascular disease among adults in the United States. *Soc. Sci. Med.* 2010;71(5):1027–36.

11. Byberg L, Zethelius B, McKeigue PM, Lithell HO. Changes in physical activity are associated with changes in metabolic cardiovascular risk factors. *Diabetologia* 2001;44(12):2134–9.

12. Cappuccio FP, Taggart FM, Kandala N-B, et al. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep* 2008;31(5):619–26.

13. Center for Disease Control: Physical Activity [Internet]2014;http://www.cdc.gov/physicalactivity/data/facts.htm.Available from: http://www.cdc.gov/physicalactivity/data/facts.htm

14. Chase JM, Lockhart CK, Madden KM. Accelerometer-based measures of sedentary behavior and cardio- metabolic risk in active older adults. 2014;37(2):108–17.

15. Dalleck LC, Kjelland EM. The Prevalence of Metabolic Syndrome and Metabolic Syndrome Risk Factors in College-aged Students. *Am. J. Heal. Promot.* 2012;27(1):37–43.

16. Dolkas CB, Greenleaf JE. Insulin and glucose responses during bed rest with isotonic and isometric exercise. *J. Appl. Physiol.* 1977;43(6):1033–8.

17. Eckel RH, Alberti KGMM, Grundy SM, Zimmet PZ. The metabolic syndrome. *Lancet* 2010;375(9710):181–3.

18. Edwardson CL, Gorely T, Davies MJ, et al. Association of sedentary behaviour with metabolic syndrome: a meta-analysis. *PLoS One* 2012;7(4):e34916.

19. Ekstedt M, Akerstedt T, Söderström M. Microarousals during sleep are associated with increased levels of lipids, cortisol, and blood pressure. *Psychosom. Med.* 2004;66(6):925–31.

20. Fernandes J, Lofgren IE. Prevalence of metabolic syndrome and individual criteria in college students. *J Am. Coll. Health* 2011;59(4):313–21.

21. Foley D, Ancoli-Israel S, Britz P, Walsh J. Sleep disturbances and chronic disease in older adults: results of the 2003 National Sleep Foundation Sleep in America Survey. *J. Psychosom. Res.* 2004;56(5):497–502.

22. Gami AS, Witt BJ, Howard DE, et al. Metabolic syndrome and risk of incident cardiovascular events and death: a systematic review and meta-analysis of longitudinal studies. *J. Am. Coll. Cardiol.* 2007;49(4):403–14.

23. Gangwisch JE, Malaspina D, Boden-Albala B, Heymsfield SB. Inadequate sleep as a risk factor for obesity: analyses of the NHANES I. *Sleep* 2005;28(10):1289–96.

24. Grandner M a, Martin JL, Patel NP, et al. Age and sleep disturbances among American men and women: data from the U.S. Behavioral Risk Factor Surveillance System. *Sleep* 2012;35(3):395–406.

25. Gutin B, Yin Z, Humphries MC, Barbeau P. Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. *Am. J. Clin. Nutr.* 2005;81(4):746–50.

26. Hall MH, Muldoon MF, Jennings JR, Buysse DJ, Flory JD, Manuck SB. Self-reported sleep duration is associated with the metabolic syndrome in midlife adults. *Sleep* 2008;31(5):635–43.

27. Hamburg NM, McMackin CJ, Huang AL, et al. Physical inactivity rapidly induces insulin resistance and microvascular dysfunction in healthy volunteers. *Arterioscler. Thromb. Vasc. Biol.* 2007;27(12):2650–6.

28. Harvey AG, Stinson K, Whitaker KL, Moskovitz D, Virk H. The subjective meaning of sleep quality: a comparison of individuals with and without insomnia. *Sleep* 2008;31(3):383–93.

29. Healy G, Wijndaele K, Dunstan D, et al. Objectively Measured Sedentary Time , Physical Activity , and Metabolic Risk. *Diabetes Care* 2008;31(2):369–71.

30. Healy GN, Dunstan, Salmon J, et al. Breaks in Sedentary Time: Beneficial associations with metabolic risk. *Diabetes Care* 2008;31(4):661–6.

31. Helmerhorst HJF, Wijndaele K, Brage S, Wareham NJ. Objectively Measured Sedentary Time May Predict Insulin Resistance Independent of Moderate- and Vigorous-Intensity Physical Activity. *Diabetes* 2009;58:1776–9.

32. Hu FB, Li TY, Colditz GA. Television Watching and Other Sedentary Behaviors in Relation to Risk of Obesity and Type 2 Diabetes Mellitus in Women. *JAMA* 2014;289(14):1785–91.

33. Hung H-C, Yang Y-C, Ou H-Y, Wu J-S, Lu F-H, Chang C-J. The association between self-reported sleep quality and metabolic syndrome. *PLoS One* 2013;8(1):e54304.

34. Jackowska M, Dockray S, Hendrickx H, Steptoe A. Psychosocial factors and sleep efficiency: discrepancies between subjective and objective evaluations of sleep. *Psychosom. Med.* 2011;73(9):810–6.

35. Jean-louis G, Kripke DF, Ancoli-israel S. Sleep and Quality of Well-Being. *Sleep* 2000;23(8):1–7.

36. Jennings JR, Muldoon MF, Hall M, Buysse DJ, Manuck SB. Self-reported sleep quality is associated with the metabolic syndrome. *Sleep* 2007;30(2):219–23.

37. Kaminsky L a, Ozemek C. A comparison of the Actigraph GT1M and GT3X accelerometers under standardized and free-living conditions. *Physiol. Meas.* 2012;33(11):1869–76.

38. Kozey-Keadle S, Libertine A, Lyden K, Staudenmayer J, Freedson PS. Validation of wearable monitors for assessing sedentary behavior. *Med. Sci. Sports Exerc.* 2011;43(8):1561–7.

39. Kronholm E, Laatikainen T, Peltonen M, Sippola R, Partonen T. Self-reported sleep duration, all-cause mortality, cardiovascular mortality and morbidity in Finland. *Sleep Med.* 2011;12(3):215–21.

40. Kump DS, Booth FW. Alterations in insulin receptor signalling in the rat epitrochlearis muscle upon cessation of voluntary exercise. *J. Physiol.* 2005;562:829–38.

41. Kushida C a, Chang a, Gadkary C, Guilleminault C, Carrillo O, Dement WC. Comparison of actigraphic, polysomnographic, and subjective assessment of sleep parameters in sleep-disordered patients. *Sleep Med.* 2001;2(5):389–96.

42. Laaksonen D, Lakka H, Salonen J, Niskanen L, Rauramaa R, Lakka T. Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome. *Diabetes Care* 2002;25(9):1612–8.

43. Lakka H-M, Laaksonen DE, Lakka T a, et al. The metabolic syndrome and total and cardiovascular disease mortality in middle-aged men. *JAMA* 2002;288(21):2709–16.

44. Lauderdale DS, Knutson KL, Yan LL, et al. Objectively measured sleep characteristics among early-middle-aged adults: the CARDIA study. *Am. J. Epidemiol.* 2006;164(1):5–16.

45. Lockley SW, Skene DJ, Arendt J. Comparison between subjective and actigraphic measurement of sleep and sleep rhythms. *J. Sleep Res.* 1999;8(3):175–83.

46. Magee C a, Caputi P, Iverson DC. Is sleep duration associated with obesity in older Australian adults? *J. Aging Health* 2010;22(8):1235–55.

47. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the United States, 2003-2004. *Am. J. Epidemiol.* 2008;167(7):875–81.

48. Mattsson N, Rönnemaa T, Juonala M, Viikari JS a, Raitakari OT. The prevalence of the metabolic syndrome in young adults. The Cardiovascular Risk in Young Finns Study. *J. Intern. Med.* 2007;261(2):159–69.

49. Megeney LA, Elder GCB, Bonen A, Blewett CA, Effects AB. Effects of muscle activity and fiber composition on glucose transport and GLUT-4. 1993;E583–92.

50. Mesas AE, Guallar-Castillón P, López-García E, et al. Sleep quality and the metabolic syndrome: the role of sleep duration and lifestyle. *Diabetes. Metab. Res. Rev.* 2013;

51. Mikines KJ, Dela F, Tronier B, Galbo H. Effect of 7 days of bed rest on dose-response relation between plasma glucose and insulin secretion. *Am. J. Physiol.* 1989;257(1 Pt 1):E43–8.

52. Morgenthaler T, Alessi C, Friedman L, et al. Practice parameters for the use of actigraphy in the assessment of sleep and sleep disorders: an update for 2007. *Sleep* 2007;30(4):519–29.

53. Orzech KM, Salafsky DB, Hamilton LA. The state of sleep among college students at a large public university. *J Am. Coll. Health* 2011;59(7):612–9.

54. Paffenbarger R, Hyde R, Wing A, Hsieh C. Physical Activity, All-Cause Mortality, and Longevity of College Men. *N. Engl. J. Med.* 1986;314(10):605–13.

55. Sabanayagam C, Shankar A. Sleep duration and cardiovascular disease: results from the National Health Interview Survey. *Sleep* 2010;33(8):1037–42.

56. Sabia S, Dugravot A, Kivimaki M, Brunner E, Shipley MJ, Singh-Manoux A. Effect of intensity and type of physical activity on mortality: results from the Whitehall II cohort study. *Am. J. Public Health* 2012;102(4):698–704.

57. Sadeh A, Hauri J, Kripke DF. An American Sleep Disorders Association Review The Role of Actigraphy in the Evaluation of Sleep Disorders. *Sleep* 1995;18(4):288–302.

58. Santos-Lozano a, Santín-Medeiros F, Cardon G, et al. Actigraph GT3X: Validation and Determination of Physical Activity Intensity Cut Points. *Int. J. Sports Med.* 2013;34(11):975–82.

59. Sherrill DL, Kotchou K, Quan SF. Association of Physical Activity and Human Sleep Disorders. *ARCH INTERN MED* 1998;158:1894–8.

60. Silva G, Goodwin J, Sherrill D, et al. Relationship Between Reported and Measured Sleep Times :The Sleep Heart Health Study (SHHS). *J. Clin. Sleep Med.* 2007;3(6):622–30.

61. Sloane R, Snyder DC, Demark-Wahnefried W, Lobach D, Kraus WE. Comparing the 7-day physical activity recall with a triaxial accelerometer for measuring time in exercise. *Med. Sci. Sports Exerc.* 2009;41(6):1334–40.

62. Souza L De, Benedito-silva AA, Laura M, et al. Further Validation of Actigraphy for Sleep Studies. *Sleep* 2003;26(1):81–5.

63. Tonetti L, Pasquini F, Fabbri M, Belluzzi M, Natale V. Comparison of two different actigraphs with polysomnography in healthy young subjects. *Chronobiol. Int.* 2008;25(1):145–53.

64. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. *Appl. Physiol. Nutr. Metab.* 2010;35(6):725–40.

65. Troxel WM, Buysse DJ, Matthews K a, et al. Sleep symptoms predict the development of the metabolic syndrome. *Sleep* 2010;33(12):1633–40.

66. Väistö J, Eloranta A-M, Viitasalo A, et al. Physical activity and sedentary behaviour in relation to cardiometabolic risk in children: cross-sectional findings from the Physical Activity and Nutrition in Children (PANIC) Study. *Int. J. Behav. Nutr. Phys. Act.* 2014;11:55.

67. Warburton DER, Nicol CW, Bredin SSD. Health benefits of physical activity: the evidence. *CMAJ* 2006;174(6):801–9.

68. Wilson W, Castelli W, Kannel W. Coronary Risk Prediction in Adults (The Framingham Heart Study). *Am. J. Cardiol.* 1987;59:91G – 94G.

69. Wolfson AR. Adolescents and emerging adults' sleep patterns: new developments. *J. Adolesc. Health* 2010;46(2):97–9.

70. Yaggi HK, Araujo AB, McKinlay JB. Sleep duration as a risk factor for the development of type 2 diabetes. *Diabetes Care* 2006;29(3):657–61.

71. Yang X, Telama R, Hirvensalo M, Mattsson N, Viikari JS a, Raitakari OT. The longitudinal effects of physical activity history on metabolic syndrome. *Med. Sci. Sports Exerc.* 2008;40(8):1424–31.