ABSTRACT

Association Between Sleep Duration and Components of Metabolic Syndrome in Young Adults

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Metabolic Syndrome (MS), which is the clustering of several cardiovascular risk factors, has become a growing concern in today's society resulting in an increasing prevalence of cardiovascular diseases and type 2 diabetes. Once observed only in older adults, metabolic syndrome is now highly prevalent across the life span. Insufficient sleep duration has been suggested to play a role in the development of metabolic syndrome, thus it is desirable to look more closely at the effects of sleep duration on each individual risk factor. A total of 55 subjects (51% male, ages 18 – 26) were recruited and participated in this study. Their 7-day sleep duration was obtained using SenseWear equipment. Subject data collected on the participants' waist circumference, BMI, fasting blood glucose, fasting high-density lipoprotein cholesterol, fasting triglycerides, and blood pressure, which are MS variables under the National Cholesterol Education Program (NCEP)/Adult Treatment Panel III (ATP III) criteria, were obtained along with fat mass, body fat percentage, lean body mass, and calculated fat mass index. Sleep duration was positively correlated with triglycerides, fat mass, body fat percentage, and fat mass index, while negatively correlated with systolic blood pressure and lean body mass. The negative correlation with systolic blood pressure and lean body mass was lost when gender was controlled for. There were no correlations found for any of the other MS variables. These data suggest that although sleep duration did not correlate with metabolic syndrome using the NCEP ATP III definition in this inclusion controlled sample of young adults, the positive relationship observed between sleep and excess body fat, a known contributor of metabolic and cardiovascular risk, is cause for future concern.

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ASSOCIATION BETWEEN SLEEP DURATION AND COMPONENTS OF METABOLIC SYNDROME IN YOUNG ADULTS

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CHAPTER ONE

Introduction

Metabolic syndrome (MS) is a clustering of several known cardiometabolic risk factors which were shown to cause an increased risk for type 2 diabetes and cardiovascular morbidity and mortality (Grundy, Cleeman, Daniels, Donato, Eckel, Franklin, et al 2005*).* The components that make up MS consist of hypertension, hyperglycemia, dyslipidemia, and obesity. It has been estimated over 15% of people in the United States ages 20 – 39 years have MS. This number increases to nearly 35% for people ages 40 or above (Aguilar et al., 2015). It has been found that the components of MS tend to track from childhood into adulthood (Katzmarzyk, Perusse, Malina, et al. 2001; Agirbasli, Tanrikulu, Berenson, 2016), thus it would be beneficial to recognize the occurrence of these cardiometabolic factors at an early stage of life in order to slow or halt its progression.

There has been increasing evidence that sleep duration plays a role in the development of metabolic syndrome. Insufficient sleep duration has been suggested to play a role in the development of metabolic syndrome (Xi, He, Zhang, Xue, Zhou, 2014). On the other hand, too much sleep may also play a role in the development of MS, but results have been inconsistent among studies (Kanagasabai & Chaput, 2017; Ju, & Choi, 2013; Ohkuma et al., 2014).

Not many studies have looked at the association of sleep duration on the development of MS in young adults. It has been suggested that age can modify the

relationship between sleep duration and cardiometabolic risk factors, thus the role sleep plays in metabolic risk may differ compared to adults. The National Sleep Foundation recommends that young adults sleep between 7 – 9 hours. Considering that 20 – 25% of university students get an average of 6.5 hours or less of sleep each night (Lund et al., 2010; Steptoe, Peacey & Wardle. 2006), it is important to determine whether short sleep duration in young adults can lead to metabolic syndrome.

The purpose of this study was to assess the role total sleep duration has on the individual risk factors of metabolic syndrome in young adults. Since body composition plays such a large role in the development of metabolic syndrome, an additional aim of the study was to assess the association between different measures of body composition and sleep duration.

CHAPTER TWO

Materials and Methods

Participants:

A total of 60 participants aged 18 – 35 with a BMI between 18.5 – 27 kg/m^2 from Baylor University and surrounding areas were recruited for this study. All eligible subjects signed university-approved informed consent documents. Approval was granted by the Institutional Review Board for Human Subjects. Additionally, all experimental procedures involved in the study were conformed to the ethical consideration of the Helsinki Code.

SenseWear

Each participant was fitted with a physical activity monitor (SenseWear^{TM} monitors) on their non-dominant triceps muscle and were instructed to wear it for 7 continuous days. A day was considered valid if the participant wore the monitor for at least 22h. If needed, participants were allowed to remove it for showering and swimming. Once the participants concluded their 7 day assessment, SenseWear^{TM} data was downloaded into SenseWear^{TM} 7.0 Professional Software to determine sleeping parameters (2012; Pittsburg, PA). Sleep was assessed during a 24-hour period between midday and midday.

Cardiometabolic Parameters

Height was measured to the nearest 0.5cm with a stadiometer. Weight was determined after voiding by using a calibrated electronic scale with a precision of 0.02kg (Detecto, Webb City, MO). Participants were weighed with no shoes and minimal

clothing. The reading was recorded to the nearest 0.1kg. Body Mass index was calculated as weight (kg) · height $(m)^{-2}$.

The National Cholesterol Education Program (NCEP) Adult Treatment Panel III (ATP III) was used as a guideline to determine which variables to use for metabolic risk. NCEP ATP III requires three out of five risks to be present in order to be diagnosed with metabolic syndrome. These include a waist circumference (WC) over 107 centimeters in men or 77 centimeters in women, blood pressure over 130/85 mmHg, fasting triglyceride (TG) level over 150 mg/dl, fasting blood glucose over 100 mg/dl, and fasting high-density lipoprotein (HDL) cholesterol level less than 40 mg/dl in males or 50 mg/dl in females.

Systolic (SBP) and diastolic (DBP) blood pressure was measured by using an aneroid sphygmomanometer following standard clinical procedures. Two measurements were taken 5 minutes apart and the average of the two was recorded.

About 20mL of blood was obtained by standard phlebotomy after a 12-hour fasting period. The blood sample was centrifuged at 3,500 rpm for 20 minutes and transferred into serum labeled microtubes. The serum was analyzed for HDL, low density lipoprotein, TG, and glucose.

Body Composition

Percent body fat (BF%), fat mass (FM), and lean body mass (LBM) were determined with the use of a whole body Dual X-Ray Absorptiometry (DXA) and were analyzed by the same Hologic-certified member of the research team. All scans were performed after a 12h fasting period. Subjects were asked to lie in a supine position while

the scan was performed. Fat mass index (FMI) was calculated using fat mass (kg) · height(m)$^{-2}$.

Statistical Analysis

All statistical analyses were performed using SPSS software version 25.0 (IBM, Armonk, New York). Pearson bivariate correlation was used to assess the relationship of sleep duration and metabolic risk factors and body composition variables. One way ANOVAs were used to compare the variables by gender and sleep groups.
Results were considered significant at $p<0.05$.

CHAPTER THREE

Results

Sixty total participants were recruited for the study but five had to have their data excluded from the analysis due to failure of wearing the activity monitor for a minimum of 22 hours daily. The percent of participants with specific metabolic risk factors is listed in Table 1. Of the risks for metabolic syndrome, 44% of the participants had at least 1 risk factor present. Descriptive characteristics of all participants, as well as divided between males and females, are listed in Table 2. Of the participants, 60% were Caucasian while the rest were African American, Hispanic, Asian, or mixed. Using BMI, 58.2% of participants were normal weight, 41.8% were overweight, and 0% were considered obese. However, in regards to BF%, 60% of participants were classified as normal weight, 32.7% were overweight (males: 20-25%; females: 30-35%), and 7.3% were obese (males>25%; females: >35%). The participants average sleep duration was 6.86 hours with 60% of the participants with sleep less than 7 hours a night.

Table 1: Percent of participants with metabolic risk factors.

	% of participants
Waist Circumference [a]	6%
Blood Pressure > 130/85 mmHg	4%
TG > 150 mg/dl	4%
HDL[b]	13%
Glucose > 100 mg/dl	26%

[a] indicates > 40 inches in males, or >35 inches in females.
[b] indicates less than 40 mg/dl in males or 50 mg/dl in women.

Table 2: Descriptive data for all participants and participants divided by sex.

	Total Mean ± SD (n=55)	Male Mean ±SD (n=28)	Female Mean ±SD (n=27)	p Value
Age	20.8 ± 1.7	21.1 ± 1.6	20.6 ± 1.8	p>0.05
Height (cm)	172.7 ± 10.5	180.1 ± 8.2	165.1 ± 6.3	p<0.01*
Weight (kg)	71.7 ± 12.8	80.3 ± 10.6	62.7 ± 7.9	p<0.01*
BMI	23.8 ± 2.4	24.7 ± 2.3	23.0 ± 2.2	p<0.01*
Waist Circumference (cm)	79.4 ± 8.6	83.4 ± 7.1	75.3 ± 8.1	p<0.01*
SBP (mmHg)	107.6 ± 10.3	112.9 ± 8.7	102.1 ± 8.9	p<0.01*
DBP (mmHg)	71.7 ± 7.5	73.1 ± 8.2	70.1 ± 6.4	p>0.05
TG (mg/dL)	79.0 ± 31.4	73.1 ± 21.3	85.2 ± 38.8	p>0.05
HDL (mg/dL)	58.3 ± 15.7	52.8 ± 12.6	64.0 ± 16.7	p<0.01*
Glucose (mg/dL)	95.6 ± 6.6	98.8 ± 6.8	92.3 ± 4.6	p<0.01*
Fat Mass (kg)	16.2 ± 4.8	14.2 ± 4.9	18.1 ± 4.8	p<0.01*
Lean Body Mass (kg)	51.8 ± 12.8	61.8 ± 9.4	41.4 ± 5.3	p<0.01*
Body fat percent	23.6 ± 7.5	18.1 ± 4.6	29.2 ± 5.5	p<0.01*
Fat Mass Index (fat mass / height^2)	5.5 ± 1.8	4.4 ± 1.3	6.6 ± 1.6	p<0.01*
Average Sleep Duration (h)	6.9 ± 0.9	6.5 ± 0.7	7.3 ± 0.9	p<0.01*

p Value between male and female participants
* = significant differences between genders

Table 3 shows the linear relationships between sleep duration and both metabolic syndrome variables and body composition. The average sleep duration for an individual was inversely correlated with body weight ($r = -0.287$, $p<0.05$), lean body mass ($r=-0.436$, $p<0.01$) and systolic blood pressure ($r=0.397$, $p<0.01$), and positively correlated with blood triglycerides ($r=0.355$, $p<0.01$), fat mass ($r=-0.453$, $p<0.01$), fat mass index

(r=0.483, p<0.01), and body fat percentage (r=0.562, p<0.01). BMI, waist circumference, DBP, blood glucose, and HDL were not related to sleep duration. When controlling for gender, the correlation between sleep duration and blood triglycerides, fat mass, fat mass index, and body fat percentage remained although slightly diminished. The negative association with lean body mass and systolic blood pressure was lost.

Table 3: Correlation between average sleep duration.

	Sleep Duration Correlation	Sleep Duration Correlation (Controlled for Gender)
Weight	-0.287[b]	0.023
BMI	-0.191	-0.042
Waist Circumference	-0.143	0.079
SBP	-0.397[a]	-0.217
DBP	-0.213	-0.143
TAG	0.355[a]	0.306[b]
Fat Mass	0.453[a]	0.333[b]
Lean Body Mass	-0.436[a]	-0.159
Body fat percentage	0.562[a]	0.396[a]
FMI	0.483[a]	0.303[b]
Glucose	-0.211	0.003
HDL	0.243	0.102

a = p<0.01; b = p<0.05

The participants were then divided into two groups according to average sleep duration following the National Sleep Foundation guidelines. Table 4 shows the descriptive differences between these two groups. The Sleep Duration <7 group was significantly higher in SPB, DBP, and LBM, while significantly lower in TAG, BF%, and FMI.

Table 4: Descriptive data and ANOVA of low and high sleep duration groups.

	Sleep Duration <7 h (n=33)	Sleep Duration ≥7 h (n = 22)	
	Mean ± SD	Mean ± SD	P Value
Age (y)	20.82 ± 1.8	20.86 ± 1.6	p>0.05
Height (cm)	174.1 ± 9.8	170.8 ± 11.3	p>0.05
Weight (kg)	74.2 ± 12.2	67.8 ± 13.0	p>0.05
BMI	24.4 ± 2.3	23.1 ± 2.4	p>0.05
Waist Circumference (cm)	80.9 ± 7.9	77.2 ± 9.3	p>0.05
SBP	110.2 ± 9.4	103.7 ± 10.5	p<0.05*
DBP	73.8 ± 7.6	68.5 ± 6.1	p<0.01*
TAG	74.7 ± 28.8	85.6 ± 34.7	p>0.05
HDL	57.1 ± 15.4	60.1 ± 16.3	p>0.05
Glucose	95.9 ± 5.7	95.2 ± 8.0	p>0.05
Fat Mass	15.2 ± 49.7	17.6 ± 42.2	p>0.05
Lean Body Mass	55.2 ± 12.3	46.8 ± 12.1	p<0.05*
Body fat %	21.3 ± 7.4	26.9 ± 6.6	p<0.01*
FMI	5.1 ± 1.9	6.1 ± 1.6	p<0.05*

* = significant differences between sleep groups

The data was further divided to examine the extremes within each sleep group. Participants placed in these groups were a minimum of at least one standard deviation away from the total mean sleep duration. For short sleep duration (n=8), the average sleep duration was 5.5 hours. For the long sleep duration (n=8) the average sleep duration was 8.4 hours. The low sleep group had significantly higher SBP, while significantly lower TAG, FM, BF%, and FMI.

Table 5: Descriptive data and ANOVA of the extreme low and high sleep duration group

	Low Sleep[a] (n=8)	High Sleep[b] (n = 8)	
	Mean + SD	Mean±SD	p Value
Age (y)	21.6 ± 1.8	21.3 ± 1.7	p > 0.05
Height (cm)	176.9 ± 11.3	172.3 ± 10.1	p > 0.05
Weight (kg)	72.9 ± 13.2	70.9 ± 9.9	p > 0.05
BMI	23.1 ± 1.9	23.9 ± 2.6	p > 0.05
WC (cm)	78.5 ± 6.3	80.6 ± 8.3	p > 0.05
SBP (mmHg)	115 ± 6.4	104.3 ± 9.9	p <0.05*
DBP (mmHg)	75.3 ± 9.0	71.9 ± 4.5	p > 0.05
TAG (mg/dL)	60.4 ± 11.5	99.8 ± 48.2	p < 0.05*
HDL (mg/dL)	56 ± 7.7	58.9 ± 21.6	p > 0.05
Glucose (mg/dL)	98 ± 5.0	92.4 ± 5.5	p > 0.05
Fat Mass (kg)	12.5 ± 4.2	20.6 ± 4.1	p < 0.01*
Lean Body Mass (kg)	56.4 ± 13.6	46.8 ± 10.0	p > 0.05
Body Fat %	18.0 ± 7.0	30.0 ± 6.7	p < 0.01*
Average Sleep Duration (h)	5.5 ± 0.3	8.4 ± 0.5	p <0.01*

a = (mean sleep duration) – (mean SD)
b = (mean sleep duration) + (mean SD)
* = significant differences between sleep groups

CHAPTER FOUR

Discussion

Low sleep duration was a common occurrence within this population, however, the prevalence of MS was identified as being low. The data showed a strong positive relationship between sleep duration and FM, BF%, triglycerides and FMI and negative correlations, although weaker, with blood pressure, LBM, and weight. No other significant correlations were found with the remaining variables.

The most interesting finding in this study was the strong positive relationship between sleep duration and adiposity. This is in disagreement with our original hypothesis - that sleep duration would have a negative association with BF%. However. some studies suggest there is a U-curved association between sleep duration and adiposity (Chapu, Despres, Couchard & Tremblay 2008; Bailey, et. al., 2014), so this may suggest that the correlations found in this study may be within the upward curve range between sleep duration and BF% in young adults. This study did not have many participants with extremely high or low sleep durations thus hindering the ability to fully analyze the effects of the sleep duration spectrum on these variables.

There could be a number of possible explanations as to why sleep duration had a strong positive correlation with adiposity within this study of young adults. One plausible explanation could be physical activity (PA) levels. When controlling for participant PA levels, there was significant weakening of these findings. This may suggest that individuals who sleep longer tend to spend more time being sedentary which reduces

energy expenditure (Levine, Lanningham-Foster, McCrady, Krizan., & et al. 2005; Thorp, Owen, Neuhaus, & Dunstan 2011). This could partially explain why these individuals had a greater fat mass.

Furthermore, participants with longer sleep durations were found to be lower in weight even though elevated fat mass was found. This can be explained by the lower amount of LBM found in participants who sleep longer. Lower LBM may indicate that these participants may have lower energy expenditure (Brewer, Bentley, Moring, Valliant, Waddell 2017; Cunningham 1991) which can lead to increased risk of elevated FM (Hume, Yokum, Stice 2016).

Currently, a number of studies have documented an inverse relationship between sleep duration and both weight and BMI (Wu, Zhai, Zhang 2014). This study found no significant relationship with BMI, but saw an inverse relationship with weight and adiposity. This suggests that weight and BMI may not be a good variable of interest and instead body composition should be analyzed at as it can increase the clinical significance of finding a correlation between obesity and sleep duration.

There were a number of limitations in this study that should be noted. The recruited population sample was small and contained relatively healthy individuals. If the study contained more individuals with metabolic syndrome, results may be altered. Furthermore, confounding variables, such as physical activity, stress levels, and eating habits, were not accounted for. These variables may significantly alter correlations.

However, strengths of this study include the use of an activity tracker and body composition scans. The activity tracker helped to objectively account for sleep duration

with no subjective bias. Body composition scans helped to determine fat and lean body mass which is unaccounted for with weight and BMI.

In conclusion, the present study found a positive relationship between sleep duration and adiposity in young adults which is a cause for future concern as excess body fat is a known contributor to metabolic and cardiovascular risk. Future studies should obtain a larger population with a larger range of sleep durations in order to more accurately determine the association of sleep on metabolic syndrome components. Studies should also seek to exclude possible confounding variables like physical activity and cortisol

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