Full Study Title:	A Sleep Intervention for Young Adults At-Risk for Type 2 Diabetes
Short Study Title:	SLEEP-EXTEND
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Abstract

Nearly 30 million Americans have type 2 diabetes (T2DM), a disorder with serious health consequences such as cardiovascular and renal disease. Almost 90 million more have prediabetes, with estimates of 8 million undiagnosed (CDC, National Diabetes Statistics Report). Insulin resistance (IR) is a precursor to prediabetes and T2DM (NIDDK, Insulin resistance and prediabetes). There is evidence of IR in those with short sleep [normal weight (Matthews et al., 2012); obese (Liu, Kushida, & Reaven, 2013)]. The risk for developing diabetes in persons with difficulty in maintaining sleep is 1.84 times the risk of diabetes in those who do not have sleep issues which is very similar to the relative risk detected from another commonly recognized risk factor-- family history of diabetes (1.7-2.3) (Reutrakul & Van Cauter, 2014). For this pilot study we will recruit 20 young adults, accounting for attrition, age 18-25 years who have elevated HOMA-IR (based on established cut points), short sleep duration (< 7 hrs./night) and obesity (BMI ≥ 30) (another risk factor for IR), and use a two-group, pre-test/post-test experimental design including objective actigraphy data for sleep. The specific aims are to: 1) evaluate the feasibility and acceptability of a tailored intervention to extend sleep duration (SLEEP-Extend), 2) determine changes in sleep duration after SLEEP-Extend intervention, 3) evaluate IR levels before and after SLEEP-Extend, and 4) explore the potential mediators of diet and physical activity between sleep duration and IR. Screening data will include measures of sleep duration, age, IR and BMI. After enrollment, baseline data will include pre-test of sleep hygiene knowledge, self-report measures of diet and physical activity as well as one week of objective monitoring of sleep using actigraphy. After all baseline data are collected, participants will be randomly assigned to group. The SLEEP-Extend intervention group will receive sleep hygiene education and instructions to increase time in bed by one hour total each night for an additional 4 weeks. The attention control group will receive education on safety practices in an urban environment. Both groups will receive the sleep hygiene post-test immediately after the intervention, and they will continue with actigraphy monitoring for 4 weeks. After the 4-week intervention period, both groups will have measures of IR, BMI, final post-test of sleep hygiene knowledge, self-reported diet and physical activity, and an exit interview, and actigraphy data will be downloaded. This study will examine whether an intervention to extend sleep will result in behavior change to increase sleep duration and improve IR.

Introduction and Background

Type 2 diabetes (T2DM) is an increasing public health concern despite national efforts to reduce incidence as well as risk (ADA, Statistics about diabetes). Almost 30 million Americans have diabetes and nearly 90 million more have prediabetes (CDC, National Diabetes Statistics Report), all of which costs the U.S. approximately $245 billion each year (ADA, Statistics about diabetes). Once predominantly associated with middle-aged and older adults, the incidence of this disease among children and young adults has increased dramatically (ADA, Statistics about diabetes). According to the Centers for Disease Control and Prevention the incidence of diabetes in persons 0-44 years old increased 167% from 1980 to 2011 (CDC, Rate of 100 per civilian). In fact, it is estimated that if T2DM continues to increase at the present rate, the number of people under 20 years of age with T2DM could increase by up to 49% by 2050 (Imperatore, et al, 2012). In 2010, diabetes was the 7th leading cause of death (ADA, Statistics about diabetes), and this disorder can lead to serious cardiovascular, renal, and neurological problems. Many risk factors for T2DM are preventable (ADA, Are you at risk?), and most interventions aimed at preventing or delaying the onset of T2DM focus on weight loss since obesity is considered a major risk factor for developing insulin resistance (IR; a precursor to prediabetes and T2DM) and T2DM. The role of insufficient (short) sleep duration is often overlooked, even though *the relative risk for developing diabetes in persons with short sleep duration is 1.28 and those with difficulty maintaining sleep is 1.84 which is nearly that of the relative risk for diabetes in persons with a family history of diabetes (1.7-2.3*) (Reutrakul & Van Cauter, 2014). Recent guidelines published by the National

Sleep Foundation (NSF) suggest that young adults 18-25 years obtain 7-9 hours of sleep per night (NSF, NSF recommends new sleep times). Insufficient sleep and sleep deprivation are becoming more common in young adults (Petrov et al., 2014), and just under 1/3 of the individuals aged 18-24 years of age surveyed in 2009 complained of insufficient sleep ≥14 days in the past 30 days (Liu, Y. et al, 2013). A Gallop poll reported even more alarming numbers with 49% of the individuals polled between the ages of 18 and 29 reporting less than 6 hours of sleep/night (Jones, 2013). This finding is particularly concerning since *short sleep duration was identified as an independent risk factor for the development of IR and T2DM* (Reutrakul & Van Cauter, 2014). Our goal is to delay the onset of T2DM; thus, we are intervening with young adults----an age where primary prevention efforts may be most effective.

Evidence for the mechanism linking short sleep duration (< 6 hrs./night) with insulin resistance (IR) includes increased sympathetic activity, altered rhythm of cortisol secretion and increased concentration of inflammatory markers (Reutrakul & Van Cauter, 2014). Additionally, several experiments have demonstrated that sleep restriction alters leptin, and leptin-to-ghrelin (hormones that regulate appetite) ratios in healthy young adults, and hunger and appetite are reported to increase with sleep restriction (Spiegel et al, 2005). A few studies examining sleep-restricted individuals found that aspects of neurological and cognitive function, such as visuospatial processing, daytime alertness, and mood were improved after sleep was extended (Dewald-Kaufmann, Oort, & Meijer, 2013; Gumenyuk et al., 2011; Kamdar, et al., 2004). The majority of these studies only included a short time frame for the sleep intervention, and none of those studies included examination of IR. Our SLEEP-Extend intervention will occur over a 4-week period. From their regression model, Matthews et al, (2012) estimated that, based on only one additional hour of sleep, healthy adolescent boys with short sleep (< 6 hrs./night) would have an almost 9% improvement in their IR levels. One study has examined the effects of an intervention to extend sleep on glucose metabolism in healthy adults (not obese nor with pre-determined IR levels) ages 20-50 years old with less than 7 hours sleep/night (they extended sleep by one hour total each night over 6 weeks) (Leproult et al, 2015). Although there were no significant changes in IR, there were significant increases in sleep duration as well as improvements in insulin sensitivity in these healthy individuals. This study underscores the achievability of getting sleep-deprived individuals to extend their sleep duration. Our study differs from Leproult and colleagues (2015) in that we will examine individuals with IR. Our recently completed preliminary study found that almost 20% of young adults (N=32) with short sleep had IR (based on established cut points). Out of those with IR, 50% were obese (BMI ≥ 30), and this is supported by other studies with similar results (Blanco et al., 2012). We feel that, compared to Leproult's study, we will implement a stronger study design with SLEEP-Extend by including only individuals with IR and by adding a control group.

Despite increased awareness of T2DM and its risk factors, the incidence of this disorder is growing, especially in younger adults. Short sleep duration has been identified as an independent risk factor for IR and T2DM; however, few lay persons are aware of this finding. Innovative and easily implemented primary prevention efforts are needed to prevent progression of disease in those with IR, a precursor to T2DM, and addressing sleep deprivation may be one effective method. We know that development of T2DM is complex and can involve multiple factors. Our participants will have the T2DM risk factors of IR, obesity and short sleep duration, but we are focusing our attention on extending sleep duration while not intervening with nutrition, physical activity and body weight in order to better evaluate the efficacy of our sleep intervention. If our results show this tailored sleep intervention (SLEEP-Extend) is feasible and does extend sleep duration as well as provide preliminary evidence of improved IR levels in sleep-deprived young adults at risk for T2DM, then we will have a foundation for a larger study to test the efficacy of SLEEP-Extend. Additionally, this initial SLEEP-Extend intervention will be a relatively low-cost approach to reduce this one risk factor (short sleep) of T2DM. The study will provide evidence of impact in intervening with sleep duration to improve metabolic function. Only one study has explored sleep extension as an intervention for short sleep duration and studied the effects on

glucose metabolism, and no sleep extension studies were found in a population at risk for T2DM. Based on the lack of evidence, little is known about how extending sleep will impact IR.

Objectives

Aims: The aims for this pilot study of young adults ages 18-25 years old with IR (based on established cut points), short sleep (< 7 hours/night) and obesity (BMI ≥ 30) are to: 1) evaluate the feasibility and acceptability of a tailored intervention to extend sleep duration (SLEEP-Extend), 2) determine changes in sleep duration after SLEEP-Extend intervention, 3) evaluate IR levels before and after SLEEP-Extend, and 4) explore the potential mediators of diet and physical activity between sleep duration and IR. Our hypotheses are: H1: Individuals undergoing SLEEP-Extend will have longer sleep duration and increased knowledge of sleep hygiene post-intervention compared to controls and, H2: A greater proportion of the SLEEP-Extend group will have a decrease in IR compared to the control group.

Outcome Measures:

BMI and baseline blood samples will be obtained at the screening visit. All other measures will be assessed at the baseline visit and at the end of the 4-week intervention period except for the following: 1) Actigraphy watch will be worn continuously, and daily sleep diary completed for the entire study period, 2) The sleep hygiene pre/post-test and safety pre/post-test (control group only) will be given prior to intervention, immediately post intervention and at end of 4-week intervention period (3 time points), 3) Participant characteristics questionnaire only at baseline, and 4) Both groups will receive the exit survey at end of 4 week intervention period. **Insulin Resistance:** A) Glucose and insulin levels will be measured from fasting serum samples. B) Insulin Resistance will be calculated from the measured glucose and insulin levels using standard formulas. Briefly, serum samples will be collected via venipuncture and analyzed at Cardiovascular Specialty Laboratories, Inc (Atlanta, GA) using standard laboratory approaches with calibrated equipment (See letters of cooperation, from Dr. Anh Le and Dr. Jeff Otis). These two values will be used to calculate the homeostatic model assessment of insulin resistance (HOMA-IR; blood glucose level X insulin level, divided by 22.5). Elevated values indicate IR. A cutoff score of HOMA-IR < 2.1 as normal and HOMA-IR ≥ 2.1 as elevated (evidence of IR) will be used as determined in non-diabetics (Esteghamati et al., 2010). **Sleep Duration:** Using wrist actigraphy (Motionlogger, AMI, Ardsley, NY) along with a sleep diary (required to help validate and score actigraphy data; Martin & Hakim, 2011), we will objectively monitor each participant's 24-hour sleep-wake cycle to obtain average sleep duration (total sleep time) for one week (baseline) prior to random assignment to group and will continue monitoring during the 4 week intervention period. All participants wear the device (looks like a watch) on the wrist continuously for a total of 5 weeks (1 week for baseline sleep and 4 weeks of intervention period), except while bathing or swimming. Leproult and colleagues (2015) had success with adults wearing a wrist actigraph continuously for a total of 8 weeks. This device contains a light sensor that stores activity counts in 1-minute epochs and will detect the onset and offset of sleep using concurrent data from sleep diaries (Buysse et al., 2008; Morgenthaler et al., 2007). The Motionlogger was successfully validated against polysomnography on dimensions of sleep patterns: sleep onset latency, wake time after sleep onset, total sleep time (sleep duration), and sleep efficiency percentage (Cole et al., 1992). Data for each sleep component will be averaged over the 7 days for each week of the protocol (e.g. average sleep efficiency percentage, average total sleep duration) for analysis. Actigraphy has been compared to polysomnography to detect sleep and wakefulness and found to have a sensitivity of .965 and accuracy of .863 (Marino et al., 2013). The sleep diary is necessary to record data to help interpret actigraphy data (time in bed, time awake, and anything that occurs during the night such as waking up in the middle of the night). Participants in the SLEEP-Extend group will also use a daily sleep diary to record any sleep hygiene practices they use. Participants in the control group will use the same daily sleep diary as the SLEEP-Extend group with the difference of recording any safety practices used rather than recording sleep hygiene practices used. **Sleep Hygiene Knowledge:** To assess

the fidelity of the intervention, we are including a sleep hygiene test that will be given at 3 time points: as a pre-test, and as a post-test immediately after the education and at the end of the 4-week intervention period. The researcher-developed sleep hygiene questionnaire is based on the sleep hygiene recommendations from the NSF and the American Academy of Sleep Medicine (AASM). Participants will identify true or false if an item is recommended to facilitate sleep. Non-sleep hygiene items will be included. In addition, the control group will receive an investigator-developed instrument with the list of safety practices based on safety information they receive. Both instruments will be reviewed for content validity by a content expert and researcher with measurement expertise. **Physical activity and Dietary characteristics:** Physical activity will be measured by activity levels from the actigraphy monitor as well as self-report using the Baecke questionnaire (Baecke, Burema & Frijters, 1982)**.** Dietary habits will be measured by self-report using the 26 -item Dietary Screener (National Cancer Institute, 2015). Both the Baecke questionnaire and Dietary Screener have evidence of validity (Philippaerts, Westerterp, & Lefevre 1999; Thompson et al, 2005). Diet and physical activity are also reported to impact IR, and a recent study found that in adolescent girls, poorer diet and lower physical activity were associated with higher levels of IR (Jiménez-Pavón et al, 2013). Measuring this at baseline and after the 4-week intervention period will allow us to assess if dietary and/or physical activity were mediators between sleep duration and IR. **Adherence to the intervention**: The percent of days extending time in bed will be computed from the total number of days TIB was actually extended by one hour over the total intervention days (4 weeks = 28 days). **Exit Interview**: Participants in both groups will be interviewed after the 4-week intervention period. This investigator-developed interview will assess their satisfaction with the intervention, any difficulties implementing the intervention strategies and what they felt was most effective and if they would recommend others to participate in the intervention. The interview questions will be reviewed by a content expert and researcher with measurement expertise. **Participant Characteristics:** Will be assessed at baseline via an investigator-developed questionnaire which will include T2DM risk factors based on the ADA risk assessment tool [male gender, family history of diabetes, high blood pressure, and physical inactivity (ADA, Are you at risk?)]. Additional data will include age, marital status, and factors that may affect sleep and/or glucose/insulin levels such as work hours, health problems, and medications. Calculation of BMI from height (stadiometer) and weight (calibrated scale) using a standard formula will be obtained. These data will describe the sample, and a total T2DM risk factor score will be calculated by summing the number of risk factors. Other data will be evaluated as potential covariates. BMI will be assessed at screening and at the end of the 4 week intervention period in both groups.

Study Methods

Design: A two-group, pre-test/post-test experimental design will be used to examine the feasibility and estimate the effects of a sleep intervention (SLEEP-Extend) designed to extend sleep duration in obese, young adults with short sleep and IR. Participants will wear actigraphy watches for one week of baseline sleep data and for an additional four weeks during the intervention.

Sample/Setting: We will recruit from Emory Hospital and Emory affiliated hospitals (Children's Healthcare of Atlanta, Emory St. Joseph's, Emory Johns Creek, Emory Midtown) through nursing staff email listservs as well as through flyers on Emory University campus and in areas that might attract young adults, through course web announcements, listservs for student emails and through social media, 20 obese individuals age 18-25 years old with short sleep (duration less than 7hrs./night) and evidence of IR [HOMA-IR levels ≥ 2.1 using serum sample (Esteghamati et al., 2010)] (See Timeline). We want to ensure 10 participants are in both groups; therefore, based on our previous experience recruiting from this age group, we will recruit individuals to give us a final N=20 (10 in each group).

Inclusion criteria: 1) Age 18-25 years old, 2) Self-report short sleep, 3) BMI ≥ 30 (the World Health Organization's classification of being obese, 4) IR determined by serum analysis, 5) Be willing to extend time in bed (See intervention below) by one hour total per night, and 6) Read and speak English.

Exclusion criteria (all self-report): 1) Night shift workers (circadian disruption can alter glucose and insulin levels), 2) Diagnosed sleep disorder (e.g., sleep apnea, restless leg syndrome,) which may impact glucose, insulin, and other hormones, 3) Medical diagnosis of diabetes or pre-diabetes, 4) Pregnant or lactating women or history of gestational diabetes, 5) Actively or intentionally trying to lose or gain weight (alteration of glucose metabolism/insulin secretion), 6) Hospitalization in past 3 months for medical or psychiatric condition, or 7) Major chronic disease (e.g., cancer, Lupus). The 5-week study will be conducted during the middle of the semester when the longer holidays and final exams do not occur.

1. Data samples will not be saved/banked or archived for future use.

2. Community Participation: Our target group consists of young adults ages 18-25 that are not diagnosed with pre-diabetes or diabetes, therefore we are not recruiting from a clinic population. For this pilot and feasibility study will recruit from Emory Hospitals (nursing staff) and Emory University and surrounding areas. Persons in this group will not be involved in the design or conduct of the study outside of participation. Once data analysis is complete, participants will receive their blood sample results as well as their actigraphy results via written form (a letter will be sent to them in the manner they choose---- email or regular mail).

PROCEDURES:

For interested participants, initial screening on the telephone for age, average sleep duration, and BMI will be done and if eligible, an appointment will be set and instructions for fasting (participant will be instructed to not eat or drink anything for 8 hours) for the screening visit (Visit #1). At Visit #1 we will obtain written informed consent that will include information on screening process: eligibility of IR (from blood sample) and height and weight measures will be obtained for BMI. Blood samples will be analyzed within one week. If HOMA-IR level is elevated in these obese individuals with short sleep, then they will be contacted and 2 additional appointments will be made. If they do not have elevated HOMA-IR levels, the researcher will call and thank them for their interest and let them know they are not eligible. Visit #2, baseline (BL) visit, will be within 2 weeks of obtaining initial blood result and consent will be confirmed (for enrollment in the study) and other BL data will be collected. Also, participants will be given a sleep diary to complete and an actigraphy watch to wear for one week for BL sleep assessment. During visit #3 (intervention visit) which is one week after BL visit, the BL actigraphy data will be downloaded and the participant instructed to continue to wear the watch for 4 more weeks. Randomization to groups will occur, and each group will receive the appropriate intervention content for the group. Immediately after the intervention, the appropriate knowledge post-test will be given according to assigned group. The SLEEP-Extend group will decide on when they are able to extend their TIB. After 2 more weeks both groups will receive a telephone call to reinforce content and answer questions about extending TIB and sleep hygiene for SLEEP-Extend group and safety information in the control group. At this telephone call the final appointment will be set for 2 weeks later and for a reminder to come in fasting. Visit #4 is the at the end of the 4-week intervention period, and data collection will include drawing of blood samples, downloading of actigraphy data with return of the watch and daily sleep diary and completing responses to standard questionnaires. To strengthen the design, we have made time spent with both groups similar throughout the study. All participants will

receive $20 after one week of baseline data. At the end of the study, all participants will receive an additional $30, a certificate of appreciation and a booklet on Healthy Sleep (NHLBI, 2011). Any participants that are noted to have additional risk factors for T2DM will be provided educational material on reducing T2DM risk factors and the suggestion made to follow up with a physician. After serum blood values are analyzed, all participants will be sent a letter with their glucose, insulin and HOMA-IR information along with a description of these values and recommendation for physician follow up. The principal investigator is a registered nurse who will collect the data and administer the sleep intervention. Standard universal precautions will be used during blood draws. Additionally, a GRA, also a registered nurse, will assist with data collection.

Sample size: A target sample size of 10 in the SLEEP-Extend group and 10 in the control will be used for this feasibility study (accounting for 20% attrition) given the need for a serum blood test as part of screening a number of participants to meet strict eligibility criteria. Participants will be randomly assigned to either the control or SLEEP-Extend group using a table of random numbers.

Overview of the SLEEP-Extend Intervention: The SLEEP-Extend intervention is comprised of two components that will be administered one week after baseline data are collected. The first component consists of aiming to increase sleep duration by increasing time in bed (TIB) by one hour total per night for 4 weeks. Increasing TIB has been a successful strategy used to extend sleep duration in multiple studies (Dewald-Kaufmann, Oort, & Meijer, 2013; Gumenyuk et al., 2011; Kamdar, et al., 2004; Leproult et al., 2015). We will determine with participants when TIB can be extended for one hour total per night (either going to bed earlier or staying in bed later) depending on their preference and instructing participants to increase TIB for one hour total each night for 4 weeks. The second component of the intervention consists of one educational session regarding using sleep hygiene strategies (routine for going to sleep). Healthy sleep hygiene includes strategies such as having a regular bedtime and wake time and avoidance of stimulating food/drink or activities before bedtime (AASM, *Healthy Sleep Habits*; NSF, *Sleep Hygiene*). Participants will use a daily sleep diary to record any sleep hygiene practices they use. The control group will only receive one educational session consisting of safety practices used for an urban environment. Control group participants will use a similar daily sleep diary to record any safety practices they use.

Alternative Strategies

Although studies have shown the efficacy of extending time in bed as a method to increase sleep duration, it may be difficult for participants to increase TIB by one hour all at once immediately at the beginning of the 4-week intervention period. An alternative strategy would be to have participants slowly increase their TIB in 15 min increments over a 1-week period which may be more manageable for the participant (not too big or too small) but not to exceed a total of one hour each night. One study (unpublished work) found that using this strategy for a sleep extension intervention was efficacious and reported reduction in IR in their obese adults (Rogers et al, 2013).

Informed Consent Process and Visit Details

1. Potential subjects will contact the PI using contact information from recruitment materials
2. The PI will explain the purpose of the study and conduct initial screening for eligibility by telephone. Potential subjects will be informed that the intent of the study is to examine how sleep behaviors affect risks for developing type 2 diabetes and to determine their willingness to participate in a 4-week home-based program (intervention) focused on personal sleep behaviors.
3. The initial telephone screening will include:
    a. Obtain Consent (verbal)

b. Asking age (must be 18-25 years old) and if the subject has the ability to read and write English and their self-reported height and weight for BMI calculation;
c. Reviewing exclusion criteria [night shift worker; sleep disorder diagnosis; medical diagnosis of diabetes or pre-diabetes; currently pregnant or lactating or with history of gestational diabetes; actively participating in a weight loss program; hospitalization in past 3 months for any medical or psychiatric condition; having a major chronic illness (e.g. cancer, Lupus)]; and
d. Reviewing initial inclusion criteria to determine potential eligibility:
    i. Self-reported short sleep duration of < 7 hours/night
    ii. Asking if they are willing to participate in a 4-week program focusing on sleep behavior
    iii. Administration of the Insomnia Severity Index (valid and reliable) to determine sleep quality (Inclusion criteria includes good quality sleep and is total score of < 15)
e. If the subjects do not meet the initial inclusion criteria, they will be thanked for their interest and told they are not eligible for the study.
f. If a subject meets initial inclusion requirements:
    i. An appointment will be set up at a mutually convenient date and time, within morning hours to be able to obtain a fasting blood sample and baseline actigraphy data for sleep duration and nighttime oxygen saturation and will take place in a private room located on the university campus.
    ii. Instructions will be given for fasting prior to this first appointment (subject will be instructed to not eat or drink anything for 10 hours prior to the first appointment). The first appointment is Visit #1 (Screening Visit)

4. Visit #1 (screening visit) will include obtaining blood samples to calculate insulin resistance, 2 consecutive nights of pulse oximetry and one week of baseline sleep duration using Actigraphy monitoring. The researcher will meet the subject in a private room located on the university campus and will conduct explanation of consent.
    a. The researcher or GRA will obtain written informed consent and a copy provided to the subject.
    b. The researcher will confirm the subject has not had anything to eat or drink in the past 10 hours
    c. A registered nurse (either the researcher or GRA) will obtain the following
        i. Blood sample will be obtained using standard protocol with universal precautions to obtain fasting serum blood glucose and plasma insulin levels. These levels will be used to calculate insulin resistance. A registered nurse will pierce the subject's skin (usually in a vein located on the inside middle part of the arm) with a very small needle and take the blood into a small tube. This method of taking blood is called a venipuncture. The total amount of blood drawn is about 5 ml or 1 teaspoon. During the blood draw, the subject will feel a pinch that lasts several seconds when the blood sample is taken. The subject may have pain, dizziness, bleeding, or bruising at the site of the blood draw. There is a slight risk of infection and scarring at the site of the blood draw. However, the registered nurse will use proper technique while taking the blood sample in order to reduce unwanted effects.
        ii. After obtaining the blood sample, the subject will be offered a light snack (granola bar, crackers or cookies) to eat and water or juice to drink.

iii. Subject blood samples will be labeled using a unique identification number and will be stored in a secure laboratory at Emory University until they can be analyzed by Cardiovascular Specialty Laboratories, Inc. in Atlanta, GA. The blood samples will be destroyed by Cardiovascular Specialty Laboratories, Inc. once analysis of blood levels is completed. IBC protocol submitted and approval is pending.

d. The researcher or GRA will obtain and instruct in the following:
    i. Subject height (using a stadiometer) without shoes
    ii. Subject weight (using a calibrated scale) in light clothing and no shoes
    iii. Subject body fat analysis (using a hand-held, non-invasive calibrated scale) (Omron Body Logic Pro, Omron Healthcare, Inc., Vernon Hills, IL
    iv. Instructions for wearing the wrist actigraph [wear the wrist actigraph (Motionlogger, AMI, Ardsley, NY) continuously for 1 week (device is water resistant; however, subjects will be instructed to remove for showering or other activities requiring hands to be submerged in water) to monitor activity and rest cycles throughout the week and weekend for a total of 1 week]. The researcher or GRA will answer any questions the subject has and will provide contact information if the subject has any questions or problems with the actigraph or skin irritation around the actigraph.
    v. Instructions for completing a daily sleep diary. If the subject agrees, they will download a smart phone app called SleepBot-Sleep Cycle Alarm which is compatible with Android and iPhone (and is free) and will allow subject to record the following information. If the subject does not wish to use the SleepBot-Sleep Cycle Alarm app, they will record the following information in a paper sleep diary:
        1. Time they go to bed
        2. Time they wake up
        3. Any instances of waking up and/or getting out of bed during the night.
    vi. Instructions for wearing the pulse oximetry (WristOx$_2$; Nonan Medical Inc., Plymouth, MN). This is a non-invasive device that is worn on the wrist along with a finger sensor that will assess oxygen saturation levels during the night. A decrease in oxygen saturation levels could signify obstructive sleep apnea (OSA). A desaturation index of ≥ 5/hour potentially indicates OSA. We will exclude persons with potential OSA because OSA can alter glucose levels and lead to insulin resistance. This device will be worn on the opposite wrist from the actigraphy monitor and will only be worn during the night for 2 nights during the one week of baseline screening data collection. The researcher or GRA will answer any questions the subject has and will provide contact information if the subject has any questions or problems with the pulse oximeter.

e. After one week of baseline actigraphy and pulse oximetry monitoring, the subject will return the actigraph and pulse oximeter and data will be downloaded and analyzed for sleep duration and oxygen saturation respectively. The researcher or GRA will access sleep diary information from the SleepBot app by taking a screen-shot of the data and printing it. Sleep diary info on the screen-shot will be deleted and only a paper version of the sleep diary will be retained. If the subject used a paper sleep diary, then it will be returned to the researcher for analysis.

f. If the subject's average sleep duration is not below 7 hours per night **or** their insulin resistance level does not meet the inclusion criteria (HOMA-IR is a measure of insulin

resistance and needs to be ≥ 2.1 in order to meet inclusion criteria), **or** if their oxygen desaturation index is ≥ 5/hour they will be thanked for their interest and told they are not eligible for the study. Additionally, if the subject's oxygen desaturation index is ≥ 5/hour, they will be instructed to follow up with a health provider for assessment of possible OSA.

g. If the subject's average sleep duration is less than 7 hours per night and their HOMA-IR meets inclusion criteria (≥ 2.1) and their oxygen desaturation index is < 5/hour, then the subject will be scheduled for their study enrollment visit (Visit #2) to collect questionnaires/surveys. Subjects will be given $10 after the screening visit.

5. Visit #2 (Study Enrollment Visit): This visit is done as soon as possible following screening. The researcher or GRA will meet the subject in a private room located on the university campus. The study enrollment visit for all subjects includes randomization to the treatment or control group and completion of:
    a. Researcher-developed demographic/subject characteristics questionnaire
    b. Baecke physical activity questionnaire
    c. Dietary Screener questionnaire
    d. Meal Timing questionnaire
    e. Perceived Stress Scale
    f. Sleep Hygiene Index questionnaire
    g. Control group only: an investigator-developed safety practices questionnaire
    h. Each subject will be asked to wear the actigraphy watch continuously for 4 additional weeks and complete daily sleep diary for 4 additional weeks (as previously discussed).
    i. The intervention will be administered as follows
        i. Intervention Group (SLEEP-Extend intervention): The SLEEP-Extend intervention consists of two components:
            1. One education session (5-10 minutes) consisting of strategies for sleep hygiene which is the routine for going to sleep (an investigator-developed brochure and information based on recommendations from the American Academy of Sleep Medicine and the National Sleep Foundation will be given and reviewed with the subject)
            2. Instructions on extending time in bed by at least one hour but can be up to 2 hours total per night for 4 weeks which can be accomplished by either going to bed earlier or staying in bed later (subject will decide what works best for them).
        ii. Control group:
            1. One educational session (5-10 minutes) consisting of safety practices used for an urban environment (a safety brochure and safety information developed by the Emory Police department will be given and reviewed with the subject)
    j. At the end of Visit #2, all subjects will receive $20.

6. Follow up contact after Visit #2: The subject will be contacted weekly (via text or phone depending on their preference) to reinforce content and answer any questions. Another appointment will be made for Visit #3 (end of the 4 week intervention period) and a reminder to come in fasting as previously described.
7. Visit #3 (End of the 4-week intervention period). The researcher or GRA will meet the subject in a private room located on the university campus.
    a. The research or GRA (both are registered nurses) will obtain

i. Fasting serum blood glucose and plasma insulin levels which will be used to calculate HOMA-IR (as previously described).
ii. Dietary Screener questionnaire
iii. Baecke physical activity questionnaire
iv. Meal Timing questionnaire
v. Perceived Stress Scale
vi. Height and weight as previously described
vii. Subject body fat analysis (using a hand-held, non-invasive calibrated scale) (Omron Body Logic Pro, Omron Healthcare, Inc., Vernon Hills, IL)
viii. Both groups will be given the Sleep Hygiene Index questionnaire
ix. The Control group will also be given the Safety Practices questionnaire.
x. Actigraphy data will be downloaded and actigraph and sleep diary will be returned to researcher.
xi. Lastly, an exit interview will be conducted to provide the researcher information on areas that can be improved in the study.

b. At the end of Visit #3, all subjects will receive $30, a certificate of appreciation and the control group will also receive sleep hygiene pamphlet (same as one given to intervention group)
c. All subjects will be given the following information: The following are recommendations from the American Diabetes Association to promote a healthy lifestyle (http://www.diabetes.org/are-you-at-risk/lower-your-risk/) and the suggestion made to follow up with a physician.
d. The researcher will clean the actigraph with antiseptic alcohol-based solution wipes.

8. After serum blood values are analyzed, all subjects will be sent a letter with their glucose, insulin, and HOMA-IR results along with a description of these values and recommendation for physician follow up.
9. Subjects in the control group will be given the opportunity to receive the sleep education that was provided to the intervention group.

Analysis Plan

Data analysis will include descriptive statistics to characterize the sample and inferential statistics to compare study variables. Sleep characteristics will be expressed as percent change from beginning to end and analyzed with repeat measures ANOVA. Blood levels will also be expressed as percent change from baseline to last draw. Correlational analysis will be used with sleep variables and IR. Regression analysis including components of sleep, BMI, dietary and physical activity will be conducted to examine the association of sleep factors and IR. Responses to the exit interview questions will be content coded and interrater reliability assessed.

3. Data and Safety Monitoring and Reporting: If there is an adverse or reportable event, the IRB will be notified promptly via the eIRB reportable event form. Also, the event will be documented in a tracking log. The sponsor does not require reporting above and beyond Emory IRB reporting requirements. This study does not include more than minimal risk; however, the PI will periodically review documentation to ensure accuracy and completeness.

Protection of Human Subjects

Emory IRB approval will be obtained. Participation in the study will be voluntary and written, informed consent will be obtained. Portable data will be locked in a secured cabinet. Study participant names will be on the contact form and consents, and these will be stored separately from study questionnaires. Only the researchers will have access to each participant's identity and the data. All data will have unique number identifiers and will be stored in password/firewall-protected electronic files. The PI will work closely with the IT department to ensure computer safety. Data access will be limited to a few key personnel involved in the study. All data will be maintained in the locked filing cabinets in the PI's office at Emory University for seven years following completion of the study after which the data will be shredded. Actigraphy is not considered a dangerous procedure; however special precautions will be made to educate the participant on the removal of the actigraphy if any irritation or allergic reaction should appear. Obtaining blood specimens via venipuncture is not considered a dangerous procedure; however, aseptic technique will be used by the PI (RN) to obtain blood sample. Site will be observed for 20 minutes to ensure no bleeding is present. Any abnormal finding during the study (as stated previously) will be reported to the participant and educational materials as well as physician follow-up instructions will be provided if necessary. The blood samples will be stored in a secure laboratory at Emory University and then analyzed by Cardiovascular Specialty Laboratories, Inc (Atlanta, GA) using standard laboratory approaches with calibrated equipment (see letters of support from Dr. Anh Le and Dr. Jeff Otis). A snack will be offered after drawing blood. Participant consent form will be written at a maximum of 8th grade reading level, and participants may opt out of the study at any time point.

Minority participants will be included. Children will be excluded. The participants will be ages 18-25 years. The age range was set consistent with the National Sleep Foundation age groups and recommendations for hours of sleep needed for these groups. Children under age 18 years and adults over age 25 years have different recommendations (NSF, NSF Recommends New Sleep Times). Women will be included but those who are pregnant or lactating will be excluded due to hormonal effects on glucose metabolism. Women with a history of gestational diabetes will also be excluded because gestational diabetes is a risk factor for developing T2DM; therefore, we wanted to control for this variable.

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