Published in final edited form as:

Chronobiol Int. 2020 January ; 37(1): 123–134. doi:10.1080/07420528.2019.1689398.

The association between sleep chronotype and obesity among black and white participants of the Bogalusa Heart Study

Xunming Sun¹, Jeanette Gustat², Suzanne Bertisch³, Susan Redline³, Lydia Bazzano²

¹Center for Aging, Tulane University, New Orleans, Louisiana, USA

²Department of Epidemiology, Tulane University, New Orleans, Louisiana, USA

³Division of Sleep and Circadian Disorders, Brigham and Women's Hospital and Harvard Medical School, Boston, Massachusetts, USA

Abstract

Research indicates that sleep duration and quality are inter-related factors that contribute to obesity, but few studies have focused on sleep chronotype, representing an individual's circadian proclivity, nor assessed these factors in racially diverse middle-aged samples. We examined the associations between chronotype and obesity among black and white men and women participating in the Bogalusa Heart Study (BHS).

Body mass index (BMI) and sleep data were available for 1,197 middle-aged men and women (mean age 48.2±5.3 years) who participated in the BHS 2013–2016. Based on the reduced Morningness-Eveningness Questionnaire's cutoff values for chronotypes, we combined 'definitely morning' and 'moderately morning' types into 'morning' type, 'definitely evening' and 'moderately evening' types into 'evening' type and kept those who were "neither" type in a separate group. We used 'morning' type as the referent group. Obesity was defined as a BMI ≥ 30. Multivariable logistic regression models were used to examine associations adjusting for sex, age, education, smoking, alcohol use and drug use, depression, shift work, physical activity and sleep duration.

Evening chronotype, reported by 11.1% of participants, was associated with obesity after multi-variable adjustment, including shift work, physical activity and sleep duration (OR 1.67, 95% CI: 1.08–2.56). However, once stratified by race (black/white), this association was found only among white participants (OR=1.91, 95% CI=1.12–3.25) after full adjustment.

Corresponding author: Jeanette Gustat, PhD, MPH, Clinical Associate Professor, Department of Epidemiology, School of Public Health and Tropical Medicine, Tulane University, New Orleans, Louisiana 70112, gustat@tulane.edu.

Xunming Sun, MS, PhD student, Center for Aging, School of Medicine, Tulane University, New Orleans, Louisiana 70112

Jeanette Gustat, PhD, MPH, Clinical Associate Professor, Department of Epidemiology, School of Public Health and Tropical Medicine, Tulane University, New Orleans, Louisiana 70112

Suzanne Bertisch, MD, MPH, Assistant Professor of Medicine, Division of Sleep and Circadian Disorders, Brigham and Women's Hospital, Harvard Medical School, Boston, Massachusetts 02115

Susan Redline, MD, MPH, Professor of Sleep Medicine, Departments of Medicine, Brigham and Women's Hospital, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA 02115

Lydia Bazzano, MD, PhD, MPH, Associate Professor, Department of Epidemiology, School of Public Health and Tropical Medicine, Tulane University, New Orleans, Louisiana 70112

Declaration of interest statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

In our biracial, community-based population, evening chronotype was independently associated with obesity, specifically among white participants. Further research is needed to identify behavioral, endocrine, nutritional and genetic pathways which underlie these associations.

Keywords

Sleep chronotype; obesity; race; African American; BMI

INTRODUCTION

Obesity rates have risen to epidemic levels in the US, imposing serious public health implications, with the highest burden afflicting individuals living in the American South (CDC, 2017). In several southern American states, including Louisiana, Mississippi, and Alabama, the prevalence of obesity is over 35% (CDC, 2017). Obesity is associated with many chronic diseases including type 2 diabetes, metabolic syndrome, hypertension, coronary heart disease, stroke, osteoarthritis, and cancer as well as overall mortality (Flegal et al., 2013; Haslam & James, 2005; Renehan et al., 2008). Besides an underlying fundamental disequilibrium between energy intake and expenditure, obesity is also influenced by other possible contributors including endocrine disruptors, epigenetic risk factors and other sleep related risk factors that act either directly or through other energy intake and expenditure mediated mechanisms (Lau et al., 2007; Keith et al., 2006).

Over the past few decades, sleeping less than 6 hours per night and delaying bedtime has become more common (Asaoka et al., 2010; Iglowstein et al., 2003; Knutson et al., 2010; Roenneberg et al., 2003), and emerging evidence has identified sleep deprivation and delayed bedtime as risk factors for obesity (Marshall et al., 2008; Patel & Hu, 2008; Hasler et al., 2004). It has been suggested that circadian rhythms play an important role in the regulation of multiple molecular mechanisms that control energy balance (Baehr et al., 2000; Huang et al., 2011). Moreover, the circadian clock is comprised of peripheral clocks and a central clock (Richards & Gumz, 2012; McHill & Wright, 2017), and experimental studies show that misalignment of peripheral clocks with the central clock and external stimuli adversely influence metabolism (decreased leptin, increased glucose, increased insulin, and reversed cortisol rhythm) (Adhikary et al., 2017).

While previous studies indicate that short sleep duration (usually defined as less than 6 hours per night) and poor sleep quality are associated with a higher BMI (Cappuccio et al., 2008; Patel & Hu, 2008; Beccuti & Pannain, 2011; Marshall et al., 2008), only a few studies considered the influence of circadian preference, which may account for some of these findings. In addition to the direct role of circadian misalignment on truncated sleep, circadian preference may influence other weight-related behaviors. Individuals with evening chronotypes tend to have less regular exercise, spend more time watching TV and are more likely to eat fast food (Fleig & Randler, 2009; Gaina et al., 2006; Monk et al., 2004). Timing of eating and exercise also influences metabolism and propensity for weight gain (Gallant et al., 2012; Kang et al., 1996; Meule et al., 2012). Recent studies of adolescents found associations between evening chronotype or late bedtimes with higher BMI (Arora & Taheri,

2015; Olds et al., 2011; Jarrin et al., 2013). Studies based on large databases such as the UK Biobank and 23&Me identified associations between chronotype, chronotype loci and BMI/obesity (Lane et al., 2016; Jones et al., 2016; Hu et al., 2016; Patterson et al., 2018). Associations between evening chronotype and obesity were also identified among more specific population groups such as adolescents, college students, prediabetic patients, developmentally delayed adults and persons with bipolar disorder (Arora & Taheri, 2015; Olds et al., 2011; Li et al., 2018; Zhang et al., 2018; Anothaisintawee et al., 2018; Mikulovic et al., 2014; Soreca et al., 2009). Morning chronotype may be related to successful weight maintenance as well (Ross et al., 2016). In addition, long sleepers with evening preference tend to have a high risk of being obese or overweight (Patterson et al., 2018). Moreover, it has been proposed that evening energy intake, sugary and caffeinated beverage intake, physical exercise and psychological condition act as mediators of the association between eveningness and obesity (Maukonen et al., 2019; Li et al., 2018; Zhang et al., 2018).

However, whether the association between chronotype and obesity differs by race has not been previously explored. Ethnic disparities in obesity prevalence, for example, between Hispanic and non-Hispanic black adults (Hales et al., 2017) have been identified and explained by biological, behavioral, and socioenvironmental factors such as genetics, diet and physical activity, sedentary lifestyles and neighborhood (Krueger et al., 2015). Racial disparities have also been observed in the association between short sleep duration, chronotype and obesity (Grandner et al., 2014; Malone et al., 2016).

We explored the association between sleep chronotype and obesity in a middle-aged, Southern United States, black and white community population using data from a subset of the Bogalusa Heart Study cohort (Berenson, 2001). We hope the results of this study may lead to targeted approaches and interventions for improving future health at the intersection of sleep and metabolism.

MATERIALS AND METHODS

The Bogalusa Heart Study began in 1973 with a series of examinations on black and white residents of the community of Bogalusa, Louisiana in childhood and has continued to follow the same individuals into adulthood for the purpose of understanding the natural history of atherosclerotic cardiovascular disease as well as other health outcomes (Berenson, 2001). In this analysis, only participants who completed a comprehensive set of sleep questionnaires administered during the 2013–2016 in-person examination were included. During the 2013–2016 exam, participants also completed questionnaires on sociodemographic information, sleep condition, and lifestyle, and had anthropometric measurements taken. Those who had missing information on sleep chronotype, height or weight, or any other covariates were excluded (n=118). The analytic sample included 1,180 participants. Written informed consent was obtained from each participant and all data collection protocols were approved by the Institutional Review Board of Tulane University (IRB # 356359).

CHRONOTYPE

The reduced Morningness-Eveningness Questionnaire (rMEQ) (Adan & Almirall, 1991), a 5-item version of the Morningness-Eveningness Questionnaire (Horne & Östberg, 1976), was used in this study (rMEQ in supplement). The rMEQ has been shown to be a quick, valid (), and reliable way to assess subjective sleep timing preference (Natale et al., 2006; Chelminski et al., 2000; Di Milia et al., 2013). Chronotype was classified into ‘definitely morning’ type (22–25), ‘moderately morning’ type (18–21), ‘neither’ type (12–17), ‘moderately evening’ type (8–11) and ‘definitely evening’ type (4–7) based on Adan & Almirall’s cutoff values (Adan & Almirall, 1991). In the present study ‘definitely morning’ and ‘moderately morning’ chronotype were combined into ‘morning’ type and ‘definitely evening’ and ‘moderately evening’ chronotype were combined into ‘evening’ type to avoid having categories with small sample sizes (Adan et al., 2010; Culnan et al., 2013).

OBESITY and BMI

BMI was determined as the average weight per average height² (kg/m²), from duplicate measurements of height and weight. Obesity was defined as BMI ≥ 30. Seven participants in this study were underweight (BMI < 18.5) with the lowest BMI among them at 16.4. The underweight participants were not excluded from the sample. No significant difference in chronotype has been reported between underweight and other weight groups (Sato-Mito et al., 2011; Whittier et al., 2014).

COVARIATES

Highest level of education was categorized into 8th grade, “Elementary”; 9–12th grade, “High School”; 13–16th grade, “College” and “Master’s or above”. Respondents self-reported work schedule from six categories (day shift, afternoon shift, night shift, split shift, irregular shift/on-call, and rotating shifts). This was categorized as “Regular work” (day shift), “Shift work” (including afternoon, night, split, or irregular shift/on call and rotating shift), and “Not working”. This categorization of shift work has been shown to be associated with delayed sleep timing (Reid et al., 2018). Smoking status was classified as “current smoker” or “never/ex-smoker”; alcohol consumption was assessed as “current drinker” or “not (current drinker)”. Illicit drug use (ever) includes self-reported use of at least one of the following drugs: marijuana, crack/cocaine, heroin, methadone/codeine, speed/ecstasy/diet pills, LSD/acid/mushrooms/PCP/Special K. Physical activity was categorized into “low”, “moderate”, and “high” based on the International Physical Activity Questionnaire (IPAQ). Both the total volume and the number of days or sessions were included in the IPAQ analysis algorithms (Craig et al., 2003). Sleep duration was calculated as a daily average from the total hours of self-reported sleep during the weekdays plus the total hours of sleep on the weekends divided by seven. Sleep duration less than 6 hours was defined as “Short sleep duration”, 6–8 hours as “Medium sleep duration”, greater than 8 hours as “Long sleep duration” (Hasler et al., 2004).

Cumulative scores of 10 questions on the Center for Epidemiologic Studies Depression Scale (CES-D10) were used to assess depression status (Bjorgvinsson et al., 2013). Each

question was scored from 0–3 with higher scores indicating greater depressive symptoms. Scores equal to or above 10 were considered indicative of potential clinical depression.

STATISTICAL ANALYSIS

SPSS version 20.0 (SPSS Inc., Chicago, IL) was used for all analyses. Means ($\pm$ SD) and frequencies were used to describe characteristics for the three chronotype groups (morning, neither and evening). ANOVA and Pearson's chi-square tests were used, as appropriate, to compare differences between the chronotype groups. Since BMI was not normally distributed, multivariable binary logistic regression was used to create logistic models (and calculate odds ratios and 95% confidence intervals) for the association between chronotype and obesity (BMI $\geq$ 30). Model 1 was unadjusted, model 2 was adjusted for non-modifiable risk factors including sex, age and race. Model 3 was additionally adjusted for education level, smoking, alcohol use, illicit drug use and depression. Model 4 was additionally adjusted for shiftwork. Model 5 was additionally adjusted for physical activity level and Model 6 was additionally adjusted for sleep duration. Shiftwork was adjusted separately in Model 4 because it directly affects people's wake-up time, bedtime, sleep duration and thus likely influences the potential association between sleep chronotype and obesity related hormone secretions. Similarly, physical activity was adjusted separately in Model 5 because physical activity has been well-documented to be one of the strongest variables that is associated with obesity (Chin et al., 2016). Sleep duration was adjusted separately in Model 6 because sleep duration and chronotype are two separate and independent dimensions of sleep, also because there are abundant reports of the association between short sleep duration and obesity (Patel & Hu, 2008). In the secondary analysis, the total population was divided into 2 groups: white and black individuals. The same logistic regression models (with the exception of race as a confounder) were created as in the primary analysis to assess the racial differences on the association between sleep chronotype and obesity in black and white populations separately. An adjusted R^2 is presented for each model.

RESULTS

Over half the sample was female (58.1%) and white (66.1%). The mean age of the total sample was 48.2 years ($\pm$ 5.3 years) (Table 1). About 42.2% of the sample was classified as morning type, 11.1% as evening chronotype, 15.4% reported short sleep duration and 14.7% long sleep duration.

Individuals classified as evening chronotype were significantly more likely to be female, younger, not working, and report short sleep duration as compared to participants classified as morning and neither chronotype ($p < 0.05$ for all comparisons) (Table 1). Also, those with evening chronotype had a higher BMI, were more likely to use illicit drugs, and report depressive symptoms ($p < 0.05$ for all comparisons).

Figure 1 shows that the mean BMIs for both black and white individuals with evening chronotype are significantly higher than those with morning chronotype or those specifying neither type.

Logistic regression models showed that, compared to the morning chronotype, individuals with evening chronotype had a significantly increased odds of obesity (OR=1.69, 95%CI=1.14–2.50) (Table 2). After adjustment for sex, age, race, education level, income level, current employment, smoking, alcohol and drug use, and depressive symptoms, the association remained (OR=1.68, 95%CI=1.11–2.56). There was little change after additional adjustment of shift work, physical activity levels and sleep duration (OR=1.67, 95%CI=1.08–2.56). No significant association was seen between overall sleep duration and obesity in this analysis (data not shown). Evening chronotype was associated with obesity independent of sleep duration in this study.

To explore these associations by race, the same models were stratified by white and black participants. Logistic regression analysis showed an association between evening chronotype and higher risk of obesity compared to morning chronotype only among white participants (OR=1.78, 95%CI=1.10–2.88). The association with white participants persisted after adjustment for covariates (OR=1.91, 95%CI=1.12–3.25). However, no association between chronotype and obesity was observed among black participants (OR=1.36, 95%CI=0.61–3.04, after full adjustment).

DISCUSSION

We identified a significant positive association between evening chronotype and obesity among white individuals in a middle-aged, Southern United States, community population but not among black individuals. To our knowledge this is the first time that racial differences have been addressed in the relationship between chronotype and obesity. The observed relationship persisted after adjustment for multiple factors including depressive symptoms, sleep duration, physical activity and shiftwork. It is unlikely that depressive symptoms, sleep duration, physical activity or shiftwork has mediated the association between sleep chronotype and obesity in this study.

Amongst white participants, evening chronotype was associated with obesity while morning chronotype might be preventative for obesity. However, sleep chronotype was not a risk factor for obesity among black participants.

Racial differences in sleep chronotype have been reported previously. A cross-sectional study based on 439,933 participants in the UK Biobank study reported that the ratio of morning chronotype prevalence over intermediate chronotype was 1.4 times higher in black participants than that of their white counterparts (Malone et al., 2016). In our study, there was no statistical difference in sleep chronotype prevalence between black and white adults. However, the seemingly different results of the two studies can be attributed to a variation in chronotype classification. The difference in prevalence of “morning” plus “more morning than evening” chronotypes between black and white participants was only 1.1% in the UK Biobank study (Malone et al., 2016). In the present study, the difference in prevalence of “morning” chronotype (which combined the “definitely morning” and “moderately morning” types, comparable to the sum of “morning” and “more morning than evening” types in the UK Biobank study) between black and white individuals was 1%.

In the U.S., the obesity prevalence in Hispanic and non-Hispanic black adults is significantly higher than non-Hispanic white adults (Hales et al., 2017). In our data, the prevalence of obesity was also significantly higher in black individuals than in white individuals. Biological, behavioral, and socioenvironmental factors including genetics and epigenetics, diet and physical activity, screen time and sedentary behaviors, sleep duration, and neighborhood have been proposed to explain such ethnic disparities of obesity (Krueger et al., 2015).

Racial disparities have been observed in the association between short sleep duration and obesity. Grandner et al. (2014) discovered that the positive association between sleep deprivation and obesity only exists within black/African-American and Mexican-Americans but not non-Hispanic whites or other Hispanic/Latino or Asian groups. In their case, the racial disparities were explained by the interaction of race and sleep duration (Grandner et al., 2014; Grandner, 2016; all $p < 0.0001$). In our study, the association between evening chronotype and obesity was not explained by the interaction between race and sleep chronotype (data not shown). It is possible that white participants have different genetics, diet habits, hormone secretion patterns or light exposure than their black counterparts which, together with an evening sleep chronotype, make them more susceptible to obesity. It is also possible that in black individuals, obesity has more complex contributing risk factors other than chronotype. It is interesting that mean BMI and obesity rates were higher among black participants, but sleep chronotype is not a risk factor for obesity within black participants. Further studies are needed to examine whether the racial differences in the associations between evening chronotype and obesity observed in the current research can be replicated and to study the plausible mechanisms behind the phenomenon.

There are several hypotheses that may explain the association between evening chronotype and obesity. First, the observed association might be mediated by sleep deprivation (or insufficient sleep duration) (Anothaisintawee et al., 2018). A late sleep-wake cycle may lead to long-term sleep deprivation (Merikanto et al., 2012). Independently, insufficient sleep duration has been reported to be associated with obesity (Cappuccio et al., 2008). However, in our study the association between evening chronotype and obesity remained consistent after adjustment for sleep duration, which suggests sleep duration does not explain the association between chronotype and obesity.

Second, the association could be mediated by unhealthy diet habits, such as eating late or consuming energy-dense foods, or eating disorders. Based on a 7-year follow-up study in Finnish women, Maukonen et al. (2019) proposed that evening energy intake may play a role in obesity regardless of chronotype. Others have found that consumption of sugary (Li et al., 2018) and caffeinated beverages (Zhange et al., 2018) mediated the association between chronotype and BMI. Unhealthy eating habits such as eating late (Lucassen et al., 2013) and a tendency towards binge eating (Harb et al., 2012) were associated with evening chronotype and eating late has been associated with higher BMIs (Baron et al., 2011). Moreover, evening chronotype has been associated with increased intake of fast food, greater consumption of alcohol, soft drinks and junk snacks (Fleig & Randler, 2009; Giannotti et al., 2002; Sato-Mito et al., 2011). Simply eating and drinking more calorie-dense food could make it easier for people to become obese (Isganaitis & Lustig, 2005). Unhealthy diet habits

might be one of the potential mechanisms behind the association between chronotype and obesity in our study.

Third, psychological factors such as personality and depression might also play a role as mediators of the association between chronotype and obesity (Kanerva et al., 2012). For example, people with evening chronotypes tend to be less self-regulated and self-controlled and more likely to adopt poor diet and exercise habits (Digdon & Howell, 2008; Monk et al., 2004). Depression has been reported to be strongly associated with evening chronotype and obesity at the same time (Pabst et al., 2009). In the present study, we adjusted for physical activity and depressive symptom scores, and the association between evening chronotype and obesity remained significant. It is unlikely that depression or physical activity accounts for the association between chronotype and obesity in our study.

Fourth, it is possible that changes in light exposure, melatonin and other hormones played a role in the association between evening chronotype and obesity. Decreased melatonin secretion has been reported to be responsible for obesity through the dysregulation of energy balance as well as brown tissue activation (Cipolla-Neto et al., 2014). Melatonin secretion is activated by the central circadian clock located in the suprachiasmatic nuclei (SCN) and inhibited by light exposure (Zisapel, 2018). The secretion timing and concentration of melatonin are associated with the wavelength and intensity of both the exposed diurnal and nocturnal light (Kozaki et al., 2016; Green et al., 2017). Melatonin secretion follows the 24-hour cycle directed by the SCN which usually starts when light diminishes, peaks shortly after midnight, ends before sunrise and is quickly cleared from human bodies after the cessation of melatonin production (Adamsson et al., 2016; Farhadi et al., 2016). The early evening onset, midnight peak, morning offset pattern of melatonin secretion works for most human beings who are free of circadian pathological conditions. Exceptions are those individuals living in latitudes with large seasonal differences in photoperiod length, whose onset, acrophase, offset profiles and amplitude of melatonin usually oscillate due to significant change in daily light exposure across four seasons (Adamsson et al., 2016). It has been reported that while the onset, acrophase and offset of the endogenous melatonin secretion profile in individuals with an early chronotype is advanced compared to that of late chronotype, the melatonin amplitude is similar. (Adan et al., 2012). It is possible that for people with evening chronotypes, the morning daylight exposure would disrupt the tail of their set melatonin secretion phase regardless of their wake-up time. In studies with mice, artificial light exposure at night has been shown to lead to increased body weight (Fonken et al., 2013). This correlation may be mediated by disturbed food timing and metabolic signals (Fonken et al., 2010). In addition, obesity-related hormones such as ghrelin were also associated with chronotype, suggesting that appetitive hormones may contribute to obesity associations (Scheer et al., 2009). It is possible that light exposure, melatonin and other hormones regulated the association between chronotype and obesity. Unfortunately, data does not exist to explore this in the present study.

Finally, genetic associations might exist between sleep chronotype and obesity. Lane et al. (2016) and Jones et al. (2016) found that a few chronotype loci discovered by Genome Wide Association Studies were significantly associated with BMI. However, most of these chronotype loci are newly discovered and require further verification. Furthermore,

Mendelian randomization analyses have not supported any potential association between chronotype and BMI (Lane et al., 2016; Hu et al., 2016; and Jones et al., 2016). Further research is needed to evaluate the role of genetic factors in the association between chronotype and obesity.

Our data did not support any association between sleep duration itself and obesity. This is not surprising since a number of studies have found no association between sleep chronotype and sleep duration (Adan et al., 2012; Robilliard et al., 2002; Horne & Ostberg, 1976). It is possible that the relationship between sleep duration and obesity is partially confounded by sleep chronotype (Patel & Hu, 2008). Existing studies on the association between short sleep duration and obesity in adults have shown mixed results (Patel & Hu, 2008; Magee & Hale, 2012). In the current study, both the association between chronotype and obesity and the racial disparity in this association have been identified.

STRENGTHS AND LIMITATIONS

There are several strengths to this community-based study. The sample in the present study is relatively large compared to other studies examining the relationship between chronotype and obesity. This is also the first study to examine racial (black, white) differences in the association between chronotype and obesity. In addition, we were able to consider multiple potential confounders, including education, shift work and physical activity.

There are also several limitations. The study was based on cross-sectional data which precludes assessment of causality. Sleep duration was assessed using self-report data which is subject to misclassification (Jackson et al., 2018). Although we considered significant confounders such as shift work, depression, alcohol consumption and physical activity during multivariable analyses, diet information including calorie intake, eating habits, snacks and fast food intake and food composition were not included. Without diet information, we are unable to consider these potentially relevant mechanisms. Despite being widely used, the rMEQ is an assessment tool that is solely self-reported, subjective, and prone to information bias. Similarly, this study was not able to reflect other aspects of adiposity as BMI was the only index of obesity while other measures such as body fat percentage, waist-hip ratio and waist circumference were not used. In addition, the models used in this study only accounted for a limited list of variables that could influence obesity. For example, the final model only explains 8.4% of the variance in BMI among white participants and 18.0% of the variance in black participants. Inclusion of the seven underweight participants could potentially skew the results although there is a lack of evidence associating chronotype with underweight.

In conclusion, evening chronotype was significantly associated with obesity among white middle-aged adults but not black adults. Future research is needed to explore further behavioral, physiological, psychological and genetic mechanisms underlying this association.

Funding

This work was supported by NIH R35 grant R35HL135818 (S. Redline) and the following NIH grants: K12HD043451, P20GM109036, R21AG057983, R01HL121230, 2R01AG041200 and R01DK091718 (L. Bazzano).

Appendix:: Reduced Morningness-Eveningness Questionnaire (rMEQ) used in this study

1. Considering only your own “feeling best” rhythm, at what time would you get up if you were entirely free to plan your day?
 - 5:00–6:30 am [5]
 - 6:30–7:45 am [4]
 - 7:45–9:45am [3]
 - 9:45–11:00 am [2]
 - After 11:00 am [1]
2. During the first half hour after having woken in the morning, how tired do you feel?
 - Very Tired [1]
 - Fairly Tired [2]
 - Fairly Refreshed [3]
 - Very Refreshed [4]
3. At what time in the evening do you feel tired and in need of sleep?
 - 8:00–9:00 pm [5]
 - 9:00–10:15 pm [4]
 - 10:15–12:45 am [3]
 - 12:45–2:00 am [2]
 - After 2:00 am [1]
4. At what time of the day do you think that you reach your “feeling best” peak?
 - 5:00–8:00 am [5]
 - 8:00–10:00 am [4]
 - 10:00–04:45 pm [3]
 - 4:45–9:45 pm [2]
 - After 9:45 pm [1]
5. One hears about “morning” and “evening” types of people. Which ONE of these types do you consider yourself to be?

Definitely a “morning” type [6]
 More a “morning” than an “evening” type [4]
 More an “evening” type than a “morning” type [2]
 Definitely an “evening” type [0]
 NEITHER a “morning” nor “evening” type [3]

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Figure 1.

Mean BMI and Standard Deviation by chronotype in white and black participants

Note: *: The mean BMI difference between the two groups at the two ends of the same arrowed bar is statistically significant.

Table 1.Bogalusa Heart Study participant characteristics overall and by chronotype group ($\bar{x} \pm sd$ or $n(\%)$) (n=1180)

Variables	Total	Morning type ^a	Neither type ^a	Evening type ^a	P value
N (%)	1180 (100%)	498(42.2)	551(46.7)	131(11.1)	
Sex					*0.001
Male	494(41.9)	234(47.0)	220(39.9)	40(30.5)	
Female	686(58.1)	264(53.0)	331(60.1)	91(69.5)	
Mean Age(yrs)	48.2±5.3	48.7±5.2	48.1±5.1	46.6±5.7	$\ddagger$ <0.001
#Race					*0.705
White	780(66.1)	324(65.1)	371(67.3)	85(64.9)	
Black	400(33.9)	174(34.9)	180(32.7)	46(35.1)	
Education level					*0.723
Elementary (8 th grade)	28(2.4)	11(2.2)	14(2.5)	3(2.3)	
High school (9–12 th grade)	562(47.6)	242(48.6)	262(47.5)	58(44.3)	
College (13–16 th grade)	488(41.4)	197(39.6)	229(41.6)	62(47.3)	
Master's or above (17 th grade)	102(8.6)	48(9.6)	46(8.3)	8(6.1)	
Work Schedule					*<0.001
Regular work	594(50.3)	288(57.8)	271(49.2)	35(26.7)	
Shift work ^b	164(13.9)	51(10.2)	84(15.2)	29(22.1)	
Not working	422(35.8)	159(31.9)	196(35.6)	67(51.1)	
Smoking Exposure					*0.007
Current smoker	324(27.5)	126(25.3)	147(26.7)	51(38.9)	
Never/Ex-Smoker	856(72.5)	372(74.7)	404(73.3)	80(61.1)	
Current alcohol use					*0.356
Yes	668(56.6)	294(59.0)	302(54.8)	72(55.0)	
No	512(43.4)	204(41.0)	249(45.2)	59(45.0)	
Illicit Drug use ^c	423(35.8)	163(32.7)	193(35.0)	67(51.1)	*<0.001
Physical activity ^d					*0.009
High	417(35.3)	195(39.2)	185(33.6)	37(28.2)	
Moderate	451(38.2)	191(38.4)	199(36.1)	61(46.6)	
Low	312(26.4)	112(22.5)	167(30.3)	33(25.2)	
BMI(kg/cm ²)	31.4±7.7	31.1±7.3	31.1±7.5	33.9±9.7	$\ddagger$ 0.001
BMI ≥ 30	615(52.1)	244(49.0)	290(52.6)	81(61.8)	*0.031
Mean CESD Depression score ^f	9.8±4.6	9.0±4.4	10.0±4.7	11.7±4.8	<0.001
Depression (CESD >10) ^g	536(45.4)	195(39.2)	257(46.6)	84(64.1)	*<0.001
Sleep duration ^h					*0.033

Variables	Total	Morning type ^a	Neither type ^a	Evening type ^a	P value
Short (<6h/night)	182(15.4)	68(13.7)	85(15.4)	29(22.1)	
Medium (6–8h/night)	824(69.8)	366(73.5)	380(69.0)	78(59.5)	
Long (>8h/night)	174(14.7)	64(12.9)	86(15.6)	24(18.3)	

Note: sd: standard deviation

*: Two sample t-test.

†: Pearson's Chi-square test.

^a: Chronotype: cumulative scores of reduced Morningness-Eveningness Questionnaire (rMEQ), 11 was categorized as evening type, 12–17 was categorized as Neither type, 18 was categorized as morning type.

^b: Shift work: comprised of "Afternoon shift", "Night shift", "Split shift", "Irregular shift/On call" and "Rotating shift".

^c: Consumption of drugs (ever or not) includes having used at least one of the following drugs: marijuana, crack/cocaine, heroin, methadone/codeine, speed/ecstasy/diet pills, LSD/acid/mushrooms/PCP/Special K.

^d: Physical activity: Categorized by International Physical Activity Questionnaire (IPAQ) long form.

^f: Depression scores: cumulated scores of all questions from a combined depression questionnaire (derived from Center for Epidemiologic Studies Depression Scale (CES-D10)). People with higher scores are more likely to be depressed.

^g: Depression: defined by CES-D10 score ≥ 10 .

^h: Sleep duration: hours of sleep per night was calculated by [(hours of sleep on weekdays or workdays*5) + (hours of sleep on weekends*2)]/7, all self-reported. Sleep duration was categorized by short (<6h/night), medium (6–8h/night) and long (>8h/night).

Table 2.

Odds Ratios and 95% CIs of evening sleep chronotype and obesity (BMI ≥ 30)

Chronotype	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Morning	1	1	1	1	1	1
Neither	1.16(0.91–1.47)	1.15(0.90–1.47)	1.14(0.89–1.47)	1.14(0.88–1.47)	1.12(0.86–1.44)	1.12(0.87–1.45)
Evening	1.69 (1.14–2.50)	1.59 (1.06–2.38)	1.68 (1.11–2.56)	1.69 (1.10–2.60)	1.66 (1.08–2.55)	1.67(1.08–2.56)
Adjusted R ²	0.008	0.057	0.097	0.106	0.112	0.113

CI: Confidence Interval; BMI: Body Mass Index

Model 1: unadjusted.

Model 2: adjusted for sex, age and race.

Model 3: additionally adjusted for education level, smoking, alcohol use, illicit drug use, depression.

Model 4: additionally adjusted for shift work.

Model 5: additionally adjusted for physical activity level.

Model 6: additionally adjusted for sleep duration.

Table 3.

Odds Ratios and 95% CIs of association between evening sleep chronotype and obesity (BMI ≥ 30) in white and black participants

Race	Chronotype	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
White							
	Morning	1	1	1	1	1	1
	Neither	1.31 (0.97–1.77)	1.31 (0.97–1.78)	1.33 (0.98–1.81)	1.32 (0.97–1.80)	1.29 (0.94–1.76)	1.30 (0.95–1.79)
	Evening	1.78 (1.10–2.88)	1.80 (1.10–2.93)	1.93 (1.16–3.22)	1.89 (1.12–3.20)	1.86 (1.10–3.14)	1.91 (1.12–3.25)
	Adjusted R ²	0.011	0.015	0.058	0.077	0.082	0.084
Black							
	Morning	1	1	1	1	1	1
	Neither	0.96 (0.62–1.48)	0.85 (0.54–1.34)	0.81 (0.50–1.29)	0.80 (0.50–1.28)	0.80 (0.50–1.29)	0.80 (0.49–1.29)
	Evening	1.61 (0.78–3.33)	1.39 (0.65–2.97)	1.42 (0.65–3.11)	1.37 (0.62–3.04)	1.35 (0.61–3.01)	1.36 (0.61–3.04)
	Adjusted R ²	0.007	0.108	0.166	0.167	0.174	0.180

CI: Confidence Interval; BMI: Body Mass Index

Model 1: unadjusted.

Model 2: adjusted for sex and age.

Model 3: additionally adjusted for education level, smoking, alcohol use, illicit drug use, depression.

Model 4: additionally adjusted for shift work.

Model 5: additionally adjusted for physical activity level.

Model 6: additionally adjusted for sleep duration.