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The Association between Sleep Duration and Coronary Artery Disease among American Adults in 2018

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Abstract *Context:* Coronary artery disease (CAD) is the most prevalent form of heart disease in the United States. CAD has many modifiable risk factors, such as poor diet, smoking, and lack of exercise. Much like the factors above, short sleep duration is commonly reported by American adults. *Objective:* This study examines the association between sleep duration and CAD in American adults in 2018. *Methods*: We used data from adults 18 or older who participated in the 2018 Behavioral Risk Factor Surveillance System (BRFSS) cross-sectional study. The independent variable was sleep duration in hours (rounded up), and the categories were (≤5 hours, 6 hours, 7-8 hours, and ≥9 hours). The dependent variable was ever having MI, angina, or CAD as diagnosed by a healthcare professional. The frequency of CAD is presented as weighted sampling proportions. Uni- and multivariable logistic regression analysis were used to calculate unadjusted and adjusted odds ratio (OR) for CAD comparing selected characteristics and their corresponding 95% confidence interval (CI). STATA 16.1 was the statistical software we used. *Results:* Our sample included 421,983 participants. The reference value for sleep duration was between 7-8 hours. A higher percentage of participants who slept ≤5 hours (6.8% *weighted*) or ≥9 hours (7.5% *weighted*) experienced CAD as compared to those who slept 6 hours (4.1% *weighted*) or 7-8 hours (3.9% *weighted*). Logistic regression analysis indicates that individuals who slept ≤5 hours showed an increased odds of experiencing CAD based on OR 1.41 (95% CI 1.27-1.57) after adjusting for potential confounding variables. Furthermore, individuals who reported sleeping ≥9 hours also displayed increased odds of CAD (OR 1.21; 95% CI 1.03-1.42) after adjustment. The p-values for these categories were <0.001. *Conclusion:* Our study found that adults who slept 5 hours or less and those who slept 9 hours or more had an increased chance of experiencing coronary artery disease. This remained the case after adjusting for confounding variables such as age, sex, lifestyle, and comorbidities. These findings warrant further research regarding the association between sleep duration and coronary artery disease.

Keywords: *acute myocardial infarction, sleep duration, chronic sleep deprivation*

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1. Introduction

The amount of sleep a person gets affects the general condition and well-being of patients in various ways. It is said that between 6 to 8 hours of sleep is considered healthy and beneficial for the body. On the other hand, studies have shown that lack of sleep alters judgment and may cause comorbidities. However, there is limited knowledge about its association with coronary heart disease, such as myocardial infarctions (MI). The risk factors for myocardial infarctions seem endless, but some theories suggest that sleep duration may play a role. This study explores the association between sleep deprivation and the risk of developing myocardial infarctions in adults. Establishing causality between sleep duration and MIs could have important implications for sleep-targeted interventions to reduce cardiovascular risk [1].

2. Backgrounds and Theoretical Framework (Literature Review)

Our search for peer-reviewed articles was completed via the American University of Antigua College of Medicine online library. The Pub sampled database was searched using terms deemed relevant to our focus. The terms used were: "*Adults* AND *Sleep Deprivation* AND *Myocardial Infarction,*" "*Sleep Duration* AND *Myocardial infarction,*" "*Sleep* AND *Myocardial Infarction,*" and "*Sleep* AND *Coronary Artery Disease.*" Slight variations were used to ensure a thorough search. The publication date window was limited to 1/1/2000-3/7/2021. Our

search yielded 1,268 results, of which five articles were selected. Open access articles were located using Google Scholar.

Daghlas et al. (2019) [1] conducted a prospective cohort study design. 461,347 participants of the United Kingdom Biobank (UKB) who were free of any cardiovascular diseases were included in this study. The independent variable was sleep duration. This was assessed via the question regarding how many hours they sleep (including naps) in 24 hours, in which <6 hours is short and >9 hours is long. The dependent variable was the risk of developing a myocardial infarction (MI). The confounding variables that may be present include age, sex, pre-disposed conditions, psychological sleep disturbances, comorbidities, and CAD genetic risk score. This study concluded that compared to sleeping 6-9 hours per night, which is the recommended sleep time, short sleepers had a 20% increased risk of incident MI (Hazard ratio [HR] 1.20, 95% CI 1.07-1.33, p-value 0.001) and long sleepers had a 34% higher risk of incident MI (HR 1.34, 95% CI 1.13-1.58, p-value 0.0006). Healthy sleep reduces the MI risk even among those with a high genetic predisposition (HR 0.82, 95% CI 0.68-0.998). The Mendelian randomization (MR) method was consistent with a causal effect of short sleep duration on MI risk (HR 1.19, 95% CI 1.09-1.29). Overall, there were strengths and limitations within this study. The strengths: (1) The study considers the various confounders such as some comorbidities using the MR analysis; (2) A large sample size was utilized, which is essential for the validity of the study; and (3) the incorporation of analyzing genetics along with social factors (sleep duration in this case) emphasizes that social behaviors can influence specific comorbidities. On the contrary, the weaknesses are: (1) Self- reported hours of sleep which can lead to recall bias; (2) Selection of only healthy individuals leading to "collider bias;" (3) the generalizability to European ancestry; and finally (4) there was no information regarding loss to follow up with the UKB, which may lead to the misclassification of cases to controls.

Chandola et al. (2010) [2] conducted a prospective cohort study. It used questions from the General Health Questionnaire-30 on the Whitehall II cohort. The study included 10,308 participants (3413 women and 6895 men) from 20 civil service departments in London, England. Participants were between the ages of 35 and 55 years at baseline (1985-1988) and were followed up for an average of 15 years. Independent variables included sleep duration and sleep disturbance. The question about sleep duration asked about the number of hours of sleep they would have on a given average weeknight. The question about sleep disturbance included two questions related to sleep: *Have you recently* "*lost much sleep over worry?*" and "*been having restless, disturbed nights.*" The dependent variables include coronary heart disease. Coronary heart diseases were verified by using primary care and hospital records. Some confounding variables that may be present include age, sex, smoking history, alcohol consumption, diet, exercise frequency, and BMI. However, the study controlled for confounding variables, which increased the study's validity. This study concluded that in both men and women, there is an association that shows an increase in CHD in those with short sleep hours and sleep disturbances (Relative risk [RR]:1.69, 95% Confidence Interval 1.41-2.03 in men, and RR:1.33, 95% CI 1.04-1.70 in women). After controlling for confounding variables, only sleep disturbances showed an increase in CHD (RR 1.49, 95% CI 1.22-1.82 in sleep disturbances, and RR 1.20, 95% CI 0.95-1.52 in short sleep duration). Finally, the highest risk of CHD (RR: 1.55, 95% CI 1.33-1.81) was found in participants with short sleep duration and restless, disturbed nights. The study used Cox regression models to estimate both HR and CI. The strengths of this study include (1) the incorporation of more women, which previous studies had failed to do, and (2) after controlling a different number of risk factors, disturbed sleep continued to be a positive predictor for CHD. On the contrary, potential weaknesses include (1) the self-reported nature of the data about sleep hours and sleep disturbances, (2) the vague definition of sleep disturbance, and (3) the lack of information on whether participants had sleep apnea.

Sabanayagam (2010) [3] conducted a cross-sectional study. The sample was 30,397 National Health Interview Survey 2005 participants ≥18 years of age (57.1% women). Independent variables included sleep duration categorized as ≤5 hours, 6 hours, 7 hours, 8 hours, and ≥9 hours. Dependent variables were cardiovascular diseases (angina, myocardial infarction, stroke). Confounding variables may include age, sex, smoking history, alcohol consumption, diet, exercise frequency, diabetes history, and BMI. This study concluded that there was a positive association between shorter and longer sleep hours and any CVD (Odds ratio [OR] 2.20, 95% CI 1.78-2.71 in shorter sleep hours and OR1.57, 95% CI 1.31-1.89 in longer). It also concludes that MI was positively associated with shorter and longer sleep hours in the multivariable-adjusted model. This was supported by OR 1.70, 95% CI 1.31-2.22 in shorter hours, and OR 1.30, 95% CI 1.02-1.60 in longer sleep hours. The strengths of this study include that (1) it provides similar findings to previous studies, in which there was a positive association between sleep duration and CVD; (2) a large sample size was used; and (3) information was provided regarding potential confounding variables. On the other hand, there were a few weaknesses: (1) The study being a cross-sectional study is a limitation itself, as it only provides data from a specific point in time, and (2) sleep duration was reported by the participants, in which this can lead to bias. Some side notes to consider: a multivariable logistic regression model was used to assess sleep duration and the risk of any CVD. Two more multivariable models were created. The first adjusted for age and sex, and the second adjusted for other confounding variables such as smoking, diabetes, and alcohol consumption. Finally, 7 hours of sleep duration was selected as the reference value, as previous studies have shown this to be the optimal sleep duration.

Nagai et al. (2010) [4] concluded that (1) there was a positive correlation between an increased risk for hypertension and decreased sleep duration. (2) The Nurses' Health Study (2003) showed a U-shaped phenomenon between individuals having an increased risk of CHD by sleeping less than 5 hours nightly and more than 9 hours nightly. Finally (3), Liu et al. found an increased odds ratio of subjects with 5 or less hours of sleep compared to those who received 6-8 hours of sleep.

Laugsand et al. (2011) [6] concluded that the multi-adjusted HR for AMI was 1.45 (95% CI 1.18–1.80) for people with difficulties initiating sleep almost every night, 1.30 (95% CI 1.01–1.68) for those with problems maintaining sleep nearly every night, and 1.27 (95% CI 1.03–1.57) for those with a feeling of nonrestorative sleep more than once a week compared with people who never experienced these sleep difficulties.

After doing the literature review on the five articles, we could appreciate a positive direct association between chronic sleep deprivation and an increased risk of myocardial infarction. All the studies showed that short sleep duration is associated with an increased risk not only of myocardial infarction but in other cardiovascular diseases such as angina, stroke, etc. In the same way, throughout the reviewed literature, we could also appreciate a positive association between long sleep hours and an increase in myocardial infarction risk; the same was true for other cardiovascular diseases. Most of the studies could control confounding variables by stratifying for different confounding variables, which further improved the validity of the results.

3. Research Objectives and Hypothesis

3.1. Research Objective

This study examines the association between chronic sleep deprivation and CAD in American adults aged 18-65 in 2018.

3.2. Research Hypothesis

We hypothesize that American adults between 18-65 with chronic sleep deprivation will report increased odds of CAD.

3.3. Justification

The guidelines for the proposed amount of sleep for adults is seven or more hours per night [7]. However, many are unable to achieve this recommendation. Adults in Western countries often must work long hours, thus leading to a decreased amount of nightly sleep. Buell et al. cited “a prospective study in the United States showed that the standardized mortality ratio of CHD was highest among those who worked 67 hours or more a week”. Sleep deprivation can have adverse effects on cardiovascular health. Researchers have concluded that sleep deprivation may cause “increased sympathetic nervous system activity, heart rate, and vasoconstriction, as well as salt retention” [4]. Insufficient sleep may play a role in hypertension, thus leading to coronary heart disease. Lack of sleep has been associated with insulin resistance, weight gain, high blood pressure, and depression. Current public health policy recommends that there should be stricter regulation of work hours and schedules. However, this recommendation only applies to specific industries, such as aviation and medicine. There is a strong need for working hours to be more tightly regulated nationally because sleep deprivation is a public health issue that can lead to many deleterious effects on the human body, most specifically coronary heart disease.

4. Methods

4.1. Design

This study will utilize a cross-sectional design and consist of a secondary analysis of data obtained from the 2018 Behavioral Risk Factor Surveillance System (BRFSS).

4.2. Study Population

The BRFSS samples households and other non-institutional living facilities using a complex survey design that follows a multistage area probability sampling. The BRFSS is a state-based telephone survey coordinated by the Centers for Disease Control and Prevention (CDC). Self-reported information regarding chronic conditions and health risk behaviors is collected annually using telephone surveys in all 50 states, Washington DC, Guam, Puerto Rico, and the US Virgin Islands [8]. More than 400,000 adults complete the survey annually, making the BRFSS the largest telephone survey in the world [9]. Our study population will consist of U.S. adults because the BRFSS collects self-reported information from one adult (aged 18 years or over) from each randomly sampled household.

The main inclusion criteria are 18 years or older and participation in the 2018 BRFSS.

The main exclusion criteria for participants will be if they have missing data in any BRFSS items measuring the independent variable, dependent variables, and covariates relevant to this study. If participants gave one of the following responses to any of the relevant BRFSS items: “Don’t know/Not sure” or “Refused,” they will also be excluded.

4.3. Study Variables

4.3.1. Sleep Duration (Primary Independent Variable)

Sleep duration will be measured from the following question of the BRFSS: “On average, how many hours of sleep do you get in 24 hours?” Participants of the BRFSS survey were asked to provide a numerical value of the hours of sleep in 24 hours. According to Hirshkowitz et al., 7 to 9 hours for young adults and adults and 7 to 8 hours of sleep for older adults are considered appropriate [10]. The continuous variable sleep duration will be divided into four categories ≤5 hours, 6 hours, 7-8 hours, and ≥9 hours.

4.3.2. Outcome

The primary outcome of interest is a healthcare professional diagnosed with MI, angina, or coronary artery disease (CAD). The information will be obtained by asking: “Have you been told by a doctor, nurse, or another healthcare professional that you have had a heart attack, also called myocardial infarction, angina, or coronary artery disease?”

4.3.3. Possible Confounding Variables

Other covariates that will be included in the study are age indicated by the question "What is your age?", sex indicated by "Indicate sex of respondent," race/ethnicity asked by the following questions: "Are you Hispanic, Latino/a, or Spanish origin?" and "Which one or more of the following would you say is your race?", health care access indicated by the following question: "Was there a time in the past 12 months when you needed to see a doctor but could not because of cost?", marital status indicated by "Are you married, divorced/separated, widowed, never married, member of an unmarried couple?", employment status indicated by "Are you currently employed for wages or self-employed, out of work, student/homemaker/retired, unable to work?" smoking status asked by "Do you now smoke cigarettes every day, some days, or not at all?", BMI question as Four-categories of Body Mass Index (BMI): Underweight (<18.5), Normal weight (18.5-25), Overweight (25-30), Obese (>30). Physical activity participation indicated by "During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?" and comorbid chronic conditions as indicated by Has a doctor, nurse, or another health professional EVER told you that you had any of the following: Chronic Obstructive Pulmonary Disease or COPD, emphysema or chronic bronchitis, Diabetes?"

4.3.4. Statistical Analysis

We will go through four steps, and they are as follows: (1) Descriptive analysis (checking for missing data, checking frequency distributions, re-categorizing variables), (2) Bi-variate analysis: frequency distributions according to the primary exposure of sleep duration and the main outcome variable of CAD; chi-square tests will be used to check whether the variables are equally distributed or not according to main exposure/outcome variables), (3) Collinearity diagnostics (correlation analysis to check for collinearity), and (4) Unadjusted and adjusted logistic regression analysis will be used to calculate odds ratios and their corresponding 95% confidence interval. The statistical software we will use is STATA version 16.1.

4.4. Study Ethics

The study protocol will be presented to the Internal Review Board (IRB) of the Florida International University Herbert Wertheim College of Medicine for approval. This study is not considered a human subject study as it uses secondary de-identified data. No live persons will be involved in this study, with minimal risk of harm.

Table 1. Distribution of baseline characteristics of population by sleep duration

	Sleep duration								
Characteristics	<=5 hrs		6 hrs		7-8 hrs		>=9 hrs		p-value
	Unweighted N	Weighted %	Unweighted N	Weighted %	Unweighted N	Weighted %	Unweighted N	Weighted %	
Age (years)									<0.001
18-39	12,268	40.8	24,172	40.4	54,894	37.4	6,264	35	
40-64	22,099	44.1	42,585	43.2	100,917	40.4	10,663	31.1	
65-79	9,353	12.1	20,907	13.3	72,621	17.5	11,942	23.7	
80+	2,460	3.0	4,973	3.1	20,306	4.7	5,559	10.2	
Sex									<0.001
Male	20,714	48.8	43,062	50.2	112,731	48.6	14,768	45.4	
Female	25,356	51.2	49,436	49.8	135,634	51.4	19,563	54.6	
Race									<0.001
White Non-Hispanic	30,125	55.7	66,128	60.3	193,805	65.7	25,599	61.7	
Black Non-Hispanic	5,832	17.6	9,178	13.9	15,824	9.22	3,338	13.9	
Hispanic	4,631	17.4	8,247	16.7	20,331	17.5	2,681	17.7	
Other Non-Hispanic	4,684	9.3	7,598	9.1	15,315	7.66	2,249	6.77	
Employed									<0.001
Employed	21,533	54.6	53,286	63.6	128,993	59.5	9,843	35.6	
Out of Work	2,716	6.8	3,684	5.2	8,050	4.2	1,667	6.92	
Students	13,013	22.6	27,869	24.7	98,454	31.8	18,300	45.1	
Unable to work	8,429	16.1	6,920	6.5	11,066	4.53	4,269	12.3	
MedCost									<0.001
Yes	9,516	23.2	11,678	15.0	18,781	9.95	3,250	12.1	
No	36,394	76.8	80,573	85.0	228,944	90.1	31,018	87.9	
Marital Status									<0.001
Married	18,638	41.3	46,051	49.6	137,091	53.8	15,325	43.2	
Divorced	10,706	19.2	16,217	14.2	34,303	11.4	5,667	13.5	
Widowed	5,255	6.9	9,209	5.8	28,257	6.48	6,285	12.2	
Never Married	9,504	27.7	17,185	25.5	39,629	23.6	5,943	26.5	
Unmarried	1,810	4.9	3,526	5.0	8,361	4.71	1,051	4.46	

Characteristics	Sleep duration								p-value
	<=5 hrs		6 hrs		7-8 hrs		>=9 hrs		
	Unweighted N	Weighted %	Unweighted N	Weighted %	Unweighted N	Weighted %	Unweighted N	Weighted %	
Smoke									<0.001
Current Everyday	8,681	19.3	11,279	12.5	18,745	8.18	3,615	11.1	
Current Some days	2,944	7.3	4,211	5.0	8,478	4.12	1,433	4.77	
Former Smoker	11,662	23.2	24,374	23.7	68,476	24.3	10,675	26.8	
Never Smoked	21,101	50.2	49,560	58.8	144,237	63.4	17,344	57.3	
Exercise									<0.001
Yes	29,535	66.9	68,582	75.6	195,616	79	22,364	66.3	
No	16,566	33.1	23,954	24.4	52,840	21	12,007	33.7	
Stroke									<0.001
Yes	3,181	5.0	3,517	3.0	8,720	2.69	2,618	5.97	
No	42,833	95.0	88,942	97.0	239,568	97.3	31,705	94	
COPD									<0.001
Yes	7,252	12.6	7,987	6.9	16,026	5.03	4,441	10.2	
No	38,638	87.4	84,253	93.1	231,892	95	29,760	89.8	
Diabetes									<0.001
Diabetic	8,459	14.9	12,784	11.1	30,239	9.93	6,701	16	
Pre-Diabetic	1,105	2.4	1,753	1.9	4,333	1.74	739	2.13	
Non-Diabetic	36,521	82.7	77,983	86.9	213,901	88.3	26,922	81.9	
BMI									<0.001
Underweight	935	2.3	1,297	1.6	3,515	1.69	733	2.73	
Normal Weight	11,123	27.9	23,866	29.5	75,130	34	9,825	33.7	
Overweight	13,711	31.8	30,355	34.7	85,384	36.2	10,833	32	
Obese	16,852	37.9	30,707	34.2	66,936	28	10,467	31.6	

4.4.1. Sleep Duration and Age

Each sample was statistically significant, with a p-value of <0.001. Participants in the 18-39 age group had an increase in sleep duration with a weighted percentage of 40.8, in the 6-hours category, compared to those in this age group in the remaining sleep duration categories. Individuals in the 40-64 age group had an increase in sleep duration with a weighted percentage of 44 in the ≤5-hours category. The 65-79 age group had an increase in sleep duration with a weighted percent of 23.7 in the ≥9-hours category, contrasting with those in the other sleep duration categories, which had decreased amounts. The 80+ age group, similarly to the 65-79 age group, had an increase in sleep duration with a weighted percentage of 10.2 in the ≥9-hours category.

4.4.2. Sleep Duration and Sex

Males increased in the 6-hour sleep duration category, with a weighted percent of 50.2. Females increased in the ≥9-hours category with a weighted percentage of 54.6.

4.4.3. Sleep Duration and Race

The White Non-Hispanics had an increase in sleep duration, with a weighted percentage of 65.7 in the 7-8-hours category. In the Black Non-Hispanic group, there was an increase in sleep duration in the less than or equal to ≤5-hours category with a weighted percentage of 17.6. In the Hispanic race, there was an increase in sleep duration in the greater than or equal to ≥9-hours category, with a weighted percentage of 17.7. In the other Non-Hispanic group, there was an increase in sleep duration in the less than or equal to ≤5-hours category with a weighted percentage of 9.3.

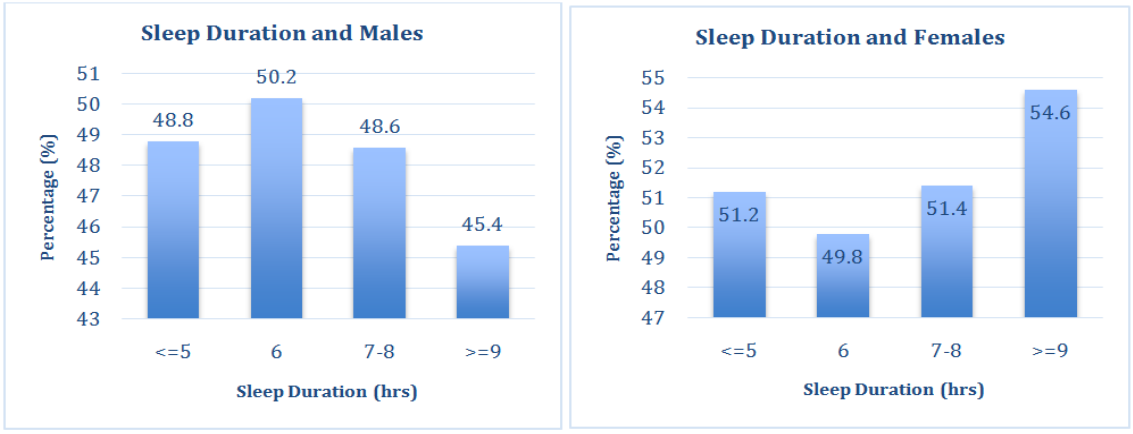

Figure 1. Sex(percentage) by Sleep Duration category

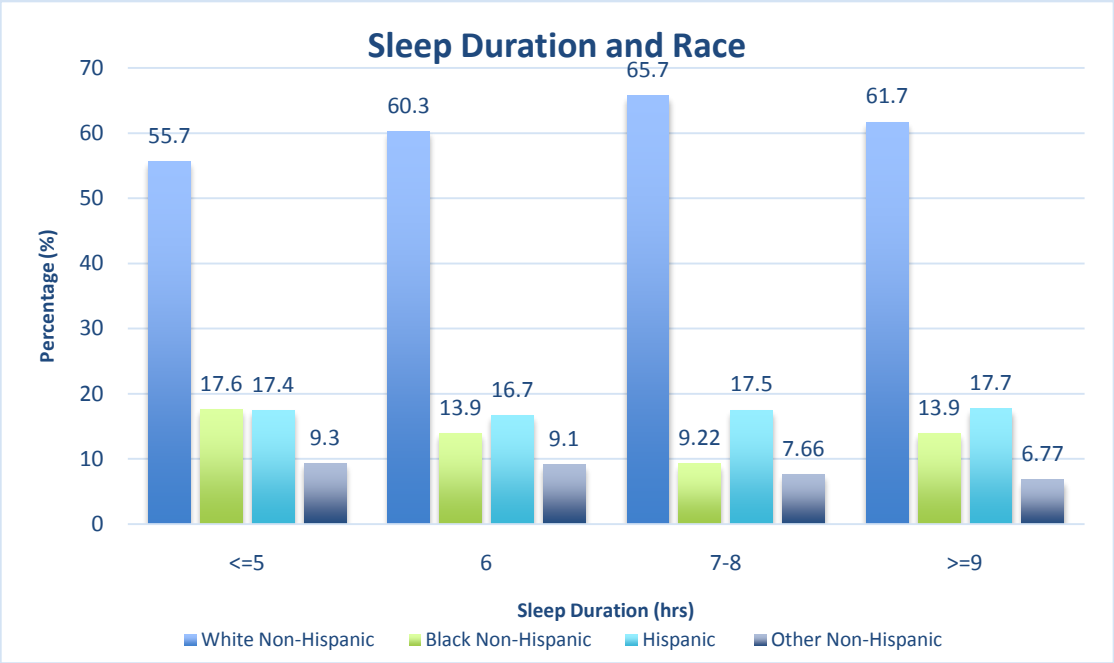

Figure 2. Race(percentage) by Sleep Duration category

4.4.4. Sleep Duration and Employment Status

Employment status was also measured. In the employed group, the sleep duration was highest in the category of 6 hours, with a weighted percentage of 63.6. The out-of-work category had an elevated sleep duration in the ≥9-hours category, with a weighted percentage of 6.92. Students or persons who were retired followed the same trend as the out-of-work group, with high sleep duration in the ≥9-hours category, with a weighted percent of 45.1. Those who reported they could not work had an increase in sleep duration in the ≤5- hours category, with a weighted percentage of 16.1.

4.4.5. Sleep Duration and Medical Costs

In the group that could afford Medical Costs, the sleep duration was elevated in the ≤5-hours category, with a weighted percentage of 23.2. On the other hand, the group that could not afford Medical Costs had an increased sleep duration in the 7-8-hours category, with a weighted percentage of 90.1.

4.4.6. Sleep Duration and Marital Status

Five marital statuses were measured: Married, Divorced, Widowed, Never married, and Unmarried. The married group had an increased sleep duration in the 7-8-hours category, with a weighted percentage of 53.8. The divorced group had an elevated sleep duration in the ≤5-hours category, with a weighted percentage of 19.2. The widowed group had an increased sleep duration in the ≥9-hours category, with a weighted percentage of 12.2. The never-married participants had a high sleep duration in the ≤5-hours category, with a weighted percentage of 27.7. The Unmarried group had an increased sleep duration in the 6-hours category, with a weighted percentage of 5.0.

4.4.7. Sleep Duration and Smoking

Current everyday smokers had an elevated sleep duration in the ≤5-hours category, with a 19.3 weighted percentage. Current Some-day smokers followed the same trend as current every day smokers, having a higher sleep duration in the ≤5-hours category, with a weighted percentage of 7.3. Former smokers had an increased sleep duration in the ≥9-hours category, with a weighted percentage of 26.8. Never smokers had an increased sleep duration in the 7-8-hours category, with a weighted percentage of 63.4.

4.4.8. Sleep Duration and Exercise

Persons who exercise had an increased sleep duration in the 7-8-hours category, with a weighted percentage of 79. Participants who did not exercise had an elevated sleep duration in the ≥9-hours category, with a weighted percentage of 33.7.

4.4.9. Sleep Duration and Stroke

Participants who had strokes had a heightened sleep duration in the ≥9-hours category, with a weighted percentage of 5.97. Participants who did not have strokes had an elevated sleep duration in the 6-hour category, with a weighted percentage of 97.0.

4.4.10. Sleep Duration and COPD

Individuals with COPD had an increased sleep duration in the ≤5-hours category, with a weighted percent of 12.6. Persons who did not have COPD had an elevated sleep duration in the 7-8-hours category with a weighted percentage of 95.

4.4.11. Sleep Duration and Diabetes

Diabetic participants had a high sleep duration in the ≥9-hours category, with a weighted percentage of 16. Pre-diabetics had an increased sleep duration in the ≤5-hours category, with a weighted percentage of 2.4. Non-diabetics had an elevated sleep duration in the 7-8-hours category, with a weighted percent of 88.3.

4.4.12. Sleep Duration and BMI

Participants in the Underweight category had an increased sleep duration in the ≥9- hours category, with a weighted percentage of 2.73. Normal weight participants had an elevated sleep duration in the 7-8-hours category, with a weighted percentage of 34. Overweight participants had an elevated sleep duration in the 7-8-hour category, with a weighted percentage of 36.2. Obese participants had an increased sleep duration in the ≤5-hour category, with a weighted percentage of 37.9.

Table 2. Distribution of coronary artery disease according to exposure of interest and other covariates

Characteristics	Coronary Artery Disease				p-value
	No		Yes		
	Unweighted N	Weighted %	Unweighted N	Weighted %	
Sleep Duration					<0.001
<=5 hours	41,975	93.2	4,205	6.8	
6 hours	87,561	95.9	5,076	4.1	
7-8 hours	235,750	96.1	12,988	3.9	
>=9 hours	31,192	92.5	3,236	7.5	
Age (years)					<0.001
18-39	96,794	99.1	804	0.855	
40-64	168,003	95.4	8,261	4.57	
65-79	103,236	89.3	11,587	10.7	
80+	28,445	86	4,853	14	
Sex					<0.001
Male	176,005	94.2	15,270	5.77	
Female	219,819	96.6	10,170	3.42	
Race					<0.001
White non-hispanic	295,663	95	19,994	5	
Black non-hispanic	32,366	96	1,806	3.99	
Hispanic	34,494	96.3	1,396	3.71	
Other non-hispanic	27,994	96.4	1,852	3.58	
Employment					<0.001
Employed	208,084	97.9	5,571	2.13	
Out of work	15,341	96.2	776	3.83	
Students/homemaker/retired	143,298	92.6	14,338	7.36	
Unable to work	26,041	86.3	4,643	13.7	
Med Cost					<0.001
Yes	40,026	94.3	3,199	5.73	
No	354,762	95.6	22,167	4.39	
Marital					<0.001
Married	205,219	95.3	11,886	4.73	
Divorced	61,526	93.4	5,367	6.61	
Widowed	43,337	88.5	5,669	11.5	
Never married	70,235	98.3	2,026	1.69	
Unmarried	14,300	97.5	448	2.49	
Smoke					<0.001
Current every day	38,786	93.3	3,534	6.66	
Current some days	15,785	93.9	1,281	6.13	
Former smoker	104,513	92.2	10,674	7.76	
Never smoked	223,050	97.2	9,192	2.85	
Exercise					<0.001
Yes	300,622	96.3	15,475	3.65	
No	95,393	92.6	9,974	7.42	
BMI					<0.001
Underweight	6,048	95.6	432	4.43	
Normal weight	114,347	96.4	5,597	3.62	
Overweight	131,416	95.4	8,867	4.59	
Obese	115,646	94.1	9,316	5.9	
Stroke					<0.001
Yes	13,049	71.7	4,987	28.3	
No	382,725	96.3	20,323	3.73	
COPD					<0.001
Yes	29,255	83.8	6,451	16.2	
No	365,732	96.3	18,811	3.69	
Diabetes					<0.001
Diabetic	49,328	85.7	8,855	14.3	
Pre-diabetic	7,315	93.3	615	6.66	
Non-diabetic	339,346	96.7	15,981	3.25	

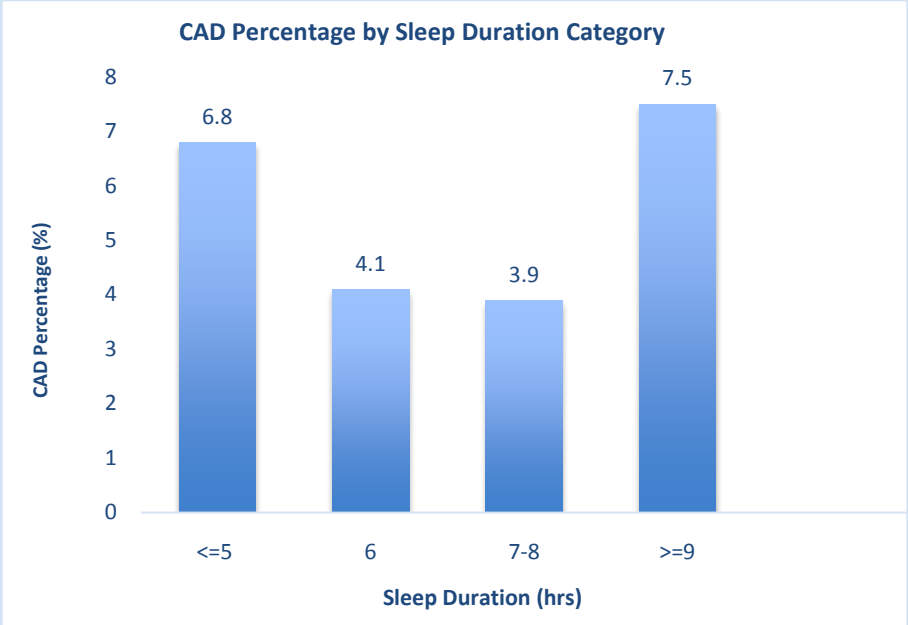

Figure 3. CAD Percentage by Sleep Duration Category

4.4.13. CAD and Sleep Duration

A higher percentage of participants who slept ≤5 hours (6.8% (*weighted*)) or ≤9 hours (7.5% (*weighted*)) experienced CAD as compared to those who slept 6 hours (4.1%(*weighted*)) or 7-8 hours (3.9% (*weighted*)).

4.4.14. CAD and Age

The percentage of participants who experienced CAD was also seen within each subsequent age group from 0.855%(*weighted*) for participants in the 18-39 group to 14%(*weighted*) in the 80 above age group.

4.4.15. CAD and Sex

Males represented a more significant percentage of participants experiencing CAD (5.77% (*weighted*) vs. 3.42% (*weighted*) in females).

4.4.16. CAD and Race

The highest percentage of participants with CAD were in the White, non-Hispanic group (5%(*weighted*)) compared to other race groups.

4.4.17. CAD and Employment Status

Participants who reported being unable to work had the highest percentage of CAD (13.7% (*weighted*)), followed by students, homemakers, and retired participants (7.36% (*weighted*)).

4.4.18. CAD and Medical Cost

Participants who were not able to seek medical care due to cost also represented a higher percentage of participants with CAD as opposed to those who were able to seek medical care (5.73% (*weighted*) vs. 4.39% (weighted)).

4.4.19. CAD and Marital Status

Widowed participants (11.5% (*weighted*)) had the highest percentage of CAD.

4.4.20. CAD and Smoking

Former smokers (7.76% (*weighted*)) had the highest percentage of CAD.

4.4.21. CAD and Exercise

Those who didn't report exercising had approximately twice as high a percentage of CAD as those who did report exercising (7.42% (*weighted*) vs. 3.65% (*weighted*)).

4.4.22. CAD and BMI

Obese, overweight, and underweight participants all had a higher percentage of CAD than participants with normal BMI, with obese patients having the highest rate (5.9%(*weighted*)).

4.4.23. CAD and Comorbidities

Regarding comorbidities, participants with a history of stroke had the highest percentage of CAD (28.3% (*weighted*)), followed by COPD (16.2% (*weighted*)), and finally, diabetes (14.3% (*weighted*)). The p-value for all categories was <0.001.

4.4.24. CAD and Sleep Duration

Individuals who reported a sleep duration of ≤5 hours had increased odds of coronary artery disease (CAD) based on the OR (95% CI), 1.81 (1.66-1.96) unadjusted, and 1.41 (1.27-1.57) after adjusting for potential confounding variables. One surprising result was seen in participants who reported 6 hours of sleep duration unadjusted. There was no significant association between the number of hours they slept and coronary artery disease; this was reflected by 1.06 (0.98-1.15). On the other hand, after adjusting for confounding variables these same participants showed increased odds of CAD because of 1.12 (1.02-1.23). Furthermore, individuals who reported a sleep duration of ≥9 hours showed high odds of CAD in both unadjusted and adjusted, 2.00 (1.78-2.24) and 1.21 (1.03-1.42), respectively. In this study, we could appreciate that more than 7-8 hours of sleep leads to increased odds of CAD.

Table 3. Association between coronary artery disease and sleep duration, and confounders

Characteristics	Unadjusted		Adjusted	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Sleep Duration				
<=5 hours	1.81 (1.66-1.96)	<0.001	1.41 (1.27-1.57)	<0.001
6 hours	1.06 (0.98-1.15)	0.152	1.12 (1.02-1.23)	0.017
7-8 hours	Reference			
>=9 hours	2.00 (1.78-2.24)	<0.001	1.21 (1.03-1.42)	0.017
Age (years)				
18-39	0.18 (0.15-0.21)	<0.001	0.27 (0.22-0.34)	<0.001
40-64	Reference			
65-79	2.50 (2.33-2.68)	<0.001	1.88 (1.69-2.10)	<0.001
80+	3.40 (3.11-3.71)	<0.001	2.71 (2.35-3.13)	<0.001
Sex				
Male	Reference			
Female	0.58 (0.54-0.62)	<0.001	0.46 (0.43-0.50)	<0.001
Race				
White non-hispanic	Reference			
Black non-hispanic	0.79 (0.71-0.88)	<0.001	0.78 (0.69-0.87)	<0.001
Hispanic	0.73 (0.64-0.84)	<0.001	1.11 (0.93-1.32)	0.251
Other non-hispanic	0.71 (0.61-0.82)	<0.001	1.00 (0.883-1.21)	0.968
Employment				
Employed	Reference			
Out of work	1.83 (1.54-2.17)	<0.001	1.48 (1.20-1.81)	<0.001
Students	3.66 (3.37-3.97)	<0.001	1.59 (1.39-1.80)	<0.001
Unable to work	7.32 (6.63-8.09)	<0.001	2.51 (2.21-2.86)	<0.001
Med Cost				
Yes	1.32 (1.21-1.44)	<0.001	1.44 (1.27-1.62)	<0.001
No	Reference			
Marital				
Married	Reference			
Divorced	1.43 (1.32-1.55)	<0.001	1.01 (0.92-1.11)	0.857
Widowed	2.63 (2.42-2.86)	<0.001	1.22 (1.09-1.36)	<0.001
Never married	0.35 (0.31-0.39)	<0.001	0.74 (0.63-0.87)	<0.001
Unmarried	0.52 (0.40-0.67)	<0.001	1.04 (0.78-1.38)	0.805
Smoke				
Current every day	2.43 (2.19-2.70)	<0.001	1.66 (1.45-1.92)	<0.001
Current some days	2.23 (1.90-2.61)	<0.001	1.92 (1.57-2.34)	<0.001
Former smoker	2.87 (2.68-3.07)	<0.001	1.49 (1.38-1.62)	<0.001
Never smoked	Reference			
Exercise				
Yes	Reference			
No	2.11 (1.98-2.25)	<0.001	1.14 (1.04-1.24)	0.003
BMI				
Underweight	1.23 (0.98-1.55)	<0.001	1.08 (0.84-1.38)	0.535
Normal weight	Reference			
Overweight	1.28 (1.17-1.40)	<0.001	0.96 (0.87-1.06)	0.44
Obese	1.67 (1.52-1.83)	<0.001	1.12 (1.00-1.24)	0.047
Stroke				
Yes	10.20 (9.40-11.07)	<0.001	3.88 (3.51-4.28)	<0.001
No	Reference			
COPD				
Yes	5.06 (4.72-5.42)	<0.001	1.92 (1.76-2.10)	<0.001
No	Reference			
Diabetes				
Diabetic	4.96 (4.64-5.31)	<0.001	2.14 (1.97-2.33)	<0.001
Pre-diabetic	2.12 (1.74-2.59)	<0.001	1.17 (0.94-1.46)	0.16
Non-diabetic	Reference			

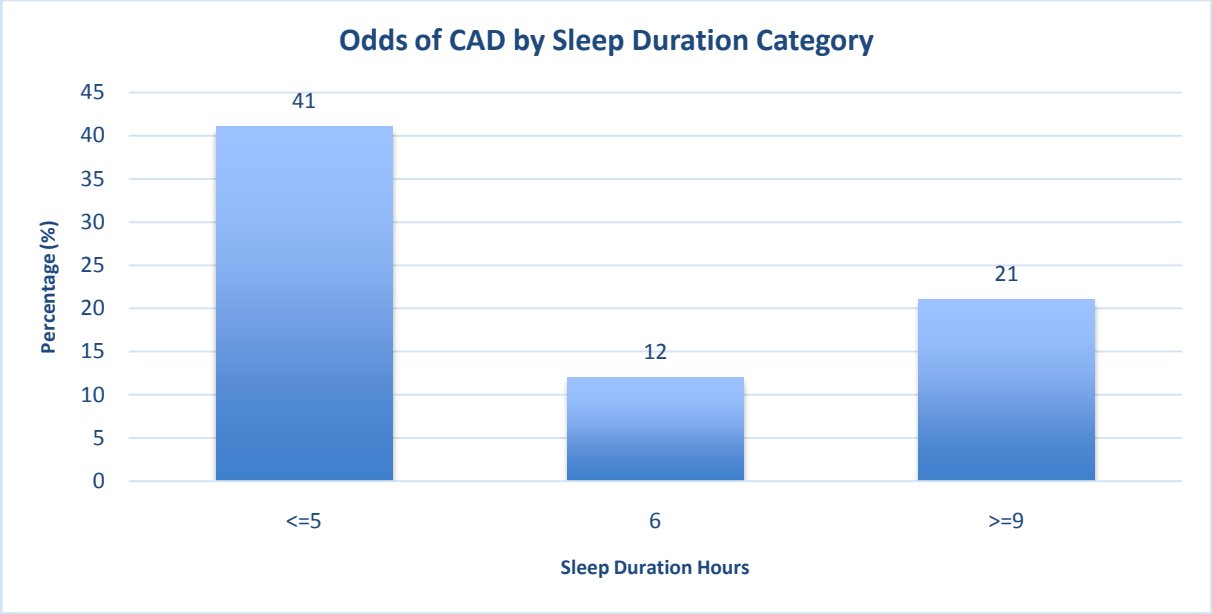

Figure 4. Odds of CAD by Sleep Duration Category. Reference value: 7-8 hours

4.4.25. CAD and Age

Compared to the reference age of 40-64, individuals aged 65-79 and 80+ had increased odds of CAD with 1.88 (1.69-2.10) and 2.71 (2.35-3.13), respectively.

4.4.26. CAD and Sex

Findings showed that women had decreased odds of CAD compared to men, with a 95% CI of 0.46 (0.43-0.50).

4.4.27. CAD and Comorbidities

Furthermore, participants who reported comorbid conditions such as stroke, COPD, and diabetes had increased odds of CAD.

4.4.28. Conclusion

This study demonstrated that adults who slept less or more than the recommended duration of 7-8 hours had increased odds of experiencing CAD. Individuals who slept ≤5 hours daily had 41% higher odds of having CAD. In the same way, individuals sleeping 6 hours a day had 12% higher odds of having CAD. Furthermore, those sleeping ≥9 hours daily had 21% higher odds of having CAD. We appreciated the increased odds of CAD with an increase in age. Compared to the reference age of 40-64, individuals aged 65-79 and 80+ had increased odds of 2 to 3 times more CAD. Also, women had about 40-50% decreased odds of CAD compared to men. Furthermore, participants with comorbid conditions such as stroke, COPD, and diabetes had increased odds of 2 to 3 times more CAD, with the highest among adults with a history of stroke. This was expected because those with pre-existing vascular conditions are at higher risk for more vascular events, such as CAD.

This study further validates the theory in previous studies that both short and long sleep duration increased the odds of CAD. One key difference between this study and previous ones is that we used 7-8 hours as the reference value for "proper sleep," and other studies used 6-9 hours. Strengths in this study included (1) using 7-8 hours as the reference value because it allowed for the use of four sleep duration categories, giving our results a more in-depth evaluation of how sleep duration is associated with CAD, (2) Large sample size; (3) Analysis completed with and without age, race, employment, med-cost, marital status, smoking, exercise, BMI, stroke, COPD, and diabetes. Our study was limited by the self-reporting of sleep duration by the study participants. One unexpected finding was that current smokers who do not smoke daily had higher odds of CAD odds than current everyday smokers. In addition, another surprising result was that overweight adults had a 4% decrease in odds of CAD.

Our hypothesis was supported by the results obtained. It was shown that in American adults aged 18-65, there are increased odds of CAD found in those who sleep less or more than the recommended amount. This study demonstrates how important getting adequate sleep is. If an individual can achieve the optimal 7-8 hours of sleep daily, they will lead a lifestyle that will help them prevent CAD in the future. Further research, which would involve monitoring sleep quality, patterns, and duration under clinical supervision, or utilizing polysomnography, would assist in understanding the association between sleep duration and coronary artery disease.

Abbreviations

BRFSS: Behavioral Risk Factor Surveillance System
CAD: Coronary Artery Disease.

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Appendix

Table A1. Inclusion and exclusion Criteria

Inclusion criteria = attributes of subjects that are essential for their selection to participate.	Exclusion criteria = responses of subjects that require their removal as subjects. Subjects with missing responses in any of the independent variable, dependent variable, or covariate items will be excluded from the study.
Participation on the 2018 BRFSS (_PSU) Answered the question about sleep duration (SLEPTIM1) Adult (aged 18 and older) (CADULT) Health Care Professional Confirmed MI, angina or CAD (CVDINFR4)	Variable (and value) in the dataset corresponding to each exclusion criteria
	Variable: Any of the BRFSS items listed in Table A2 of the Appendix
	Value: "Don't know / Not sure" or "Refused"

Database: Behavioral Risk Factor Surveillance System (2018).

Table A2. Variables in statistical analysis

	Variable	***Name in Database***	***Operational Definition***
Independent Variables	Chronic Sleep Deprivation	On average - how many hours of sleep do you get in a 24-hour period? - (SLEPTIM1)	The numerical value of sleep duration will be placed into 4 categories "≤5 hours", "6 hours", "7-8 hours" and ≥9 hours".
Dependent Variables	Diagnosis of MI, angina or coronary artery disease?	Have you been told by a doctor, nurse, or other health professional that you have had a heart attack, also called myocardial infarction, angina or coronary artery disease? (CVDINFR4)	Responses: - Yes - No
Confounders/Effect Modifiers	Age	What is your age?	Code age in years as continuous variable.
	Sex	Indicate sex of respondent. (SEX1)	Responses: "Male" or "Female"
	Race and ethnicity	Are you Hispanic, Latino/a, or Spanish origin? (_IMPRACE) Which one or more of the following would you say is your race?	BRFSS item responses will be categorized into the following: - White (non-Hispanic) - Black (non-Hispanic) - Hispanic (of any race) - Other
	Employment status	Are you currently…? (EMPLOY1)	Responses: - Employed for wages or self-employed - Out of work - Student/homemaker/retired - Unable to work
	Health care access	Was there a time in the past 12 months when you needed to see a doctor but could not because of cost? - (MEDCOST)	Response - Yes - No
	Marital status	Are you…? (MARITAL)	Responses: - Married - Divorced/Separated - Widowed - Never married - Member of an unmarried couple
	Smoking status	Do you now smoke cigarettes every day, some days, or not at all? - SMOKDAY2	Responses: Every day - Some days - Not at all
	Body Mass Index (BMI)	Four-categories of Body Mass Index (BMI) - _BMICAT5	Responses - Underweight (<18.5) - Normal weight (18.5-25) - Overweight (25-30) - Obese (>30)

	Variable	*Name in Database*	*Operational Definition*
	Physical activity participation	During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise? - EXERANY2	Response - Yes - No
	Presence of other chronic conditions	Has a doctor, nurse, or other health professional EVER told you that you had any of the following? For each, tell me "Yes," "No," or you're "Not sure." (Ever told) you had a stroke? (CVDSTRK3) (Ever told) you have Chronic Obstructive Pulmonary Disease or COPD, emphysema or chronic bronchitis? (CHCCOPD1) (Ever told) you have diabetes? (DIABETE3)	BRFSS responses: - Yes - Yes, but female told only during pregnancy - No - No, pre-diabetes or borderline diabetes These responses will be converted to the following categories: - "Yes" à Diabetic - "No, pre-diabetes or borderline diabetes" à Pre-diabetic - "Yes, but female told only during pregnancy" and "No" à Non-diabetic