HHS Public Access
Author manuscript
Obesity (Silver Spring). Author manuscript; available in PMC 2015 September 23.

Published in final edited form as:
Obesity (Silver Spring). 2014 February ; 22(2): 598–607. doi:10.1002/oby.20558.

Sleep Duration and Body Mass Index and Waist Circumference among US Adults

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Abstract

Objective—To examine the form of the relationship between sleep duration and anthropometric measures and possible differences in these relationships by gender and race or ethnicity.

Design and Methods—Data for 13,742 participants aged ≥20 years from the National Health and Nutrition Examination Survey 2005–2010 were used. Sleep duration was categorized as ≤6 (short sleepers), 7–9, and ≥10 hours (long sleepers).

Results—Short sleepers were as much as 1.7 kg/m^2 (SE 0.4) heavier and had 3.4 cm (SE 1.0) more girth than long sleepers. Among participants without depression or a diagnosed sleep disorder, sleep duration was significantly associated with body mass index (BMI) and waist circumference in an inverse linear association in the entire sample, men, women, whites, African Americans, and participants aged 20–39 years. No evidence for statistical interaction by gender and race or ethnicity was observed. Regression coefficients were notably stronger among adults aged 20–39 years. Compared to participants who reported sleeping 7–9 hours per night, short sleepers were more likely to be obese and have abdominal obesity.

Conclusions—In this nationally representative sample of US adults, an inverse linear association most consistently characterized the association between sleep duration and BMI and waist circumference.

Introduction

Sleep serves an important restorative function in humans, and a growing body of research is unraveling the possible roles of sleep in helping to maintain the homeostasis of numerous physiological functions. One area of vigorous research has been the examination of the relationships between sleep duration and anthropometric measures. The concurrent trends in the declining amount of sleep reported in the United States and the increasing prevalence of

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Disclaimer: The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Disclosure: The authors have no competing interests.

obesity have piqued the interest of researchers. Several reviews have summarized the growing body of literature relating disturbances of sleep to various anthropometric measures chiefly body mass index (1–3). Although the overall impression conveyed by many of these studies is that sleep duration is significantly associated with body mass index in adults in the majority of studies, specific gaps in the knowledge base are evident (2). First, some inconsistency in study results exists. For example, short sleep duration has more often than not been associated with increased body mass index and other anthropometric parameters but has also been associated with lower body mass index. Studies have also reported conflicting associations between long sleep duration and lower body mass index and other anthropometric parameters (4). Second, the shape of the relationship between sleep duration and anthropometric measures remains uncertain as studies have shown inverse, U-shaped, or no relationships between the two. Third, the majority of these studies have examined obesity based on body mass index as their main anthropometric measures of interest leaving the relationships between sleep duration and other anthropometric measures largely unexplained. Fourth, questions about possible gender and racial or ethnic differences remain unanswered. To provide additional insights into the relationship between sleep duration and anthropometric measures, we analyzed data from a large nationally representative sample of adults in the United States.

Methods

The present study included data from the National Health and Nutrition Examination Survey (NHANES) 2005–2010. Each 2-year cycle yields a national sample representative of the civilian, noninstitutionalized United States population selected by using a multistage, stratified sampling design. Participants were interviewed at home and were invited to attend a mobile examination center, where they were asked to complete additional questionnaires, to undergo various examinations, and to provide a blood sample. Interview and examination response rates for the three consecutive 2-year cycles exceeded 70%. The surveys received approval from the National Center for Health Statistics Research Ethics Review Board, and participants were asked to sign an informed consent form. Details about the survey may be found elsewhere (5).

Body mass index (kg/m^2) was calculated from measured weight and height. Height was measured with a stadiometer, and weight was measured on a digital weight scale with participants wearing a standard examination gown. Waist circumference was measured at the level of uppermost lateral border of the iliac crest to the nearest 0.1 cm. General obesity was defined as a body mass index ≥30 kg/m^2, and abdominal obesity was defined as a waist circumference ≥102 cm in men and ≥88 cm in women.

Sleep duration was assessed with the question “How much sleep do you usually get at night on weekdays or workdays?” Answers were recorded in whole hours, and responses of more than 12 hours were coded as 12 hours. Because the National Sleep Foundation suggests that adults should sleep 7–9 hours per night, we created the following three categories of sleeping duration: ≤6 hours, 7–9 hours, and ≥10 hours per night. We also refer to these three groups as short, normal, and long sleepers, respectively.

Covariates included age, gender, race or ethnicity (white, African American, Mexican American, other Hispanic, mixed race), educational status (<high school, high school graduate or equivalent, >high school), employment status (employed, not employed, retired), children age 17 or younger in household, smoking status (never, former, current), leisure-time physical activity, alcohol use, prescription medication use, depression score, and histories of cardiovascular disease, diabetes, chronic obstructive pulmonary disease, arthritis, thyroid problems, liver disease, cancer, and sleep disorder. Answers to questions aimed at assessing food security of children in a participant's household were considered as evidence of children age 17 or younger in that household. Current smokers were defined as participants who had smoked ≥100 cigarettes during their lifetime and were still smoking. Former smokers were defined as participants who had smoked ≥100 cigarettes during their lifetime but had stopped. Participants who had smoked <100 cigarettes during their lifetime were classified as having never smoked. To estimate leisure-time physical activity for the years 2005 to 2006, we summed the product of weekly time spent in each activity volunteered by the participant multiplied by the MET value for that activity yielding a MET-hours index. One MET is the energy expenditure of approximately 1 kcal/kg body weight/hour. For the years 2007 to 2010, the physical activity questionnaire was changed. We estimated weekly MET-hours for moderate and vigorous activities from questions that asked participants about their participation in moderate and vigorous activities, the number of days per week engaged in these activities, and the number of minutes engaged in these activities on a typical day. Using questions from the alcohol use questionnaire, three levels of alcohol use were created: excessive (men: >2 drinks per day; women: >1 drinks per day); moderate (men >0–<2 drinks per day; women: >0–1 drink per day); and none. Prescription medication use was determined from the question "In the past month have you used or taken medication for which a prescription is needed?". A depression score was calculated from answers to the Patient Health Questionnaire (PHQ-9). A score of 10 or higher was considered as compatible with the presence of depression. Participants were considered to have cardiovascular disease if they had ever been told by a doctor or other health professional that they had congestive heart failure, coronary heart disease, angina, heart attack, or stroke. Participants who responded affirmatively to the question "Have you ever been told by a doctor or health professional you have diabetes or sugar diabetes?" were considered to have diagnosed diabetes. Those who answered that they had not been so told or that they had borderline diabetes were not considered to have diagnosed diabetes. Participants were defined as having chronic obstructive pulmonary disease if they responded that they still had chronic bronchitis or ever had emphysema. The question "Have you ever been told by a doctor or other health professional that you have a sleep disorder?" was used to determine the presence or absence of a history of a sleep disorder.

We limited the analyses to men and nonpregnant women who were aged ≥20 years. Differences in means and percentages were tested with *t*-tests and chi-square tests, respectively. For the three groups of sleep duration, we used linear regression analysis to calculate adjusted least-square means of body mass index and waist circumference after adjusting for covariates shown above and noted in the tables. In addition, we estimated the linear regression coefficients for sleep duration as a continuous parameter. We also examined the associations between sleep duration status and general and abdominal obesity using log-linear analysis with robust variance estimator. For analyses stratified by race or ethnicity, we only present results for whites, African Americans, and Mexican Americans. We used SUDAAN for our statistical analyses to account for the complex survey design. Sampling weights were used to calculate estimates (means, percentages, regression coefficients, and prevalence ratios). Statistical significance was defined as $P < 0.05$.

Results

A total of 16,539 participants aged ≥20 years had an examination. After excluding pregnant women, 16,157 participants remained of whom 15,905 participants had a value for body mass index and 15,216 had a value for waist circumference. Once participants with missing values for other study variables were excluded, 13742 participants were included in the analyses.

The analytic sample included 6904 men, 6838 women, 6783 whites, 2743 African Americans, 2498 Mexican Americans, and 1718 participants of another race or ethnicity. The median age of the sample was 46 years. About 36.6% (SE 0.7) of participants reported sleeping 6 or fewer hours per night, 61.4% (SE 0.7) reported sleeping 7–9 hours per night, and 2.0% (SE 0.1) reported sleeping 10 or more hours per night.

The means and percentages of several study covariates differed significantly among the three categories of sleep duration (Table 1). The age-adjusted percentages of whites, adults with at least a high-school education, and employed adults were highest among participants reporting sleeping 7–9 hours per night. Furthermore, the percentages of adults reporting cardiovascular disease, diabetes, chronic obstructive pulmonary disease, and arthritis were lowest among participants reporting sleeping 7–9 hours per night.

As sleep duration increased, mean levels of body mass index and waist circumference decreased (Table 2). After maximal adjustment, short sleepers were as much as 1.7 kg/m^2 (SE 0.4) heavier and had a waist circumference as much as 3.4 cm (SE 1.0) greater than long sleepers.

The relationship between sleep duration as a continuous variable and the anthropometric variables is presented in Table 3. Prior to adjustment for the depression score and diagnosed sleep disorder status, significant inverse relationships for body mass index and waist circumference were noted for the entire sample, men, women, whites, and participants aged 20–39 years. In addition, a significant inverse relationship for body mass index was observed for participants aged ≥60 years, and significant nonlinear relationships for body mass index and waist circumference were observed for participants age 40–59 years. The associations between sleep duration and the anthropometric parameters in models 1–3 varied by age with the associations being notably stronger among the youngest adults (20–39 years). When a squared term for sleep duration was added to models 1–4 in an effort to examine possible departures from linearity, the term was statistically significant only for participants aged 40–59 years for model 4.

When the depression score and diagnosed sleep disorder status were added to the models (model 5 in Table 3), nonlinear associations for body mass index and waist circumference emerged among all participants, whites, and participants aged 40–59 years. Figure 1 shows that adjusted mean body mass index and waist circumference among all participants increased with increasing sleep duration through 5 hours per night and then trended down.

We also examined the associations between sleep duration and body mass index and waist circumference after excluding participants with a depression score ≥10 and participants who reported having been diagnosed as having a sleep disorder (Table 4). No significant nonlinear associations as reflected by the squared term for sleep duration in any of the models were observed. Inverse linear associations were detected for all participants, men, women, whites, African Americans, and participants aged 20–39 years. Furthermore, inverse linear associations for body mass index were found among Mexican Americans and participants aged 40–59 years. Figure 2 presents the adjusted mean body mass index and waist circumference in function of the number of hours slept per night for all participants.

Compared to the participants who reported sleeping 7–9 hours per night, short sleepers were more likely to be obese (adjusted prevalence ratio [aPR]: 1.10, 95% confidence interval [CI]: 1.03, 1.16) and to have abdominal obesity (aPR: 1.07, 95% CI: 1.02, 1.11) (Table 5). Significant findings were observed among men, and participants aged 20–39 years. Furthermore, long sleepers were less likely to be obese than the reference group among all participants, whites, and those aged 40–59 years as shown by the fully adjusted model. The only statistically significant interaction was for age in the two models with the most adjustment. The adjusted prevalence ratios for the maximally adjusted model were 0.97 (95% confidence interval: 0.95, 0.99) per hour of sleep for obesity and 0.98 (95% CI: 0.96, 0.99) per hour of sleep for abdominal obesity.

Discussion

Our results that were obtained from a large nationally representative sample of adults in the United States demonstrate that sleep duration showed inverse linear associations with body mass index and waist circumference in models that did not adjust for depression score and diagnosed sleep disorders or in models that excluded participants with depression or a sleep disorder. Furthermore, these associations held for many of the major demographic subgroups examined in this study, and the associations did not differ by gender or among three major racial or ethnic groups. The association was particularly strong among adults aged 20–39 years.

Our results indicating that sleep duration is associated with anthropometric abnormalities are consistent with the findings of the majority of previous studies (2,3). The results of our analyses suggested that sleep duration was associated with body mass index and waist circumference in an inverse, linear fashion. In a review of 17 cross-sectional studies examining the associations between sleep duration and anthropometric measures in adults, seven studies found no association, six found a U-shaped association, and four found a negative linear association (3). The authors of that review did not offer possible explanations for the substantial heterogeneity that characterized the included studies. We surmise that differences in characteristics of participants, exclusion criteria, adjustment factors, location of studies, and assessment of sleep duration may partially account for the observed differences among studies. In another review of 20 cross-sectional studies in adults, five studies found no association, four studies found a inverse linear association, three studies found a U-shaped association, eight studies found that short sleep duration was associated with increased body mass index or obesity, and one study found that short sleep duration was associated with decreased body mass index (2). Some of the limitations inherent in many of these studies mentioned by the authors may help to explain some of the heterogeneity among the studies that were reviewed including definitions of normal sleep duration, lack of objective sleep duration measurements, and a focus on mostly nocturnal sleep duration. Like many of the investigations reviewed, our study used a single question to determine sleep duration.

We found no evidence to suggest that the associations between sleep duration and anthropometric measures varied by gender. Few studies have examined this issue. In a study of 3127 men and women aged 32–62 from France, body mass index was higher in short sleepers among women but not in men (6). In an analysis of 1585 male and 1888 female participants of the Coronary Artery Risk Development in Young Adults study, sleep duration was not associated with body mass index or waist circumference in either men or women in maximally adjusted models (7). Although gender differences in the association between sleep duration and anthropometric parameters appeared not to have been formally tested, the authors commented that the association between sleep duration and body composition appeared stronger and more consistent in women than men. Given the scarcity of data in this area, more research examining possible gender differences in the relationship between short sleep duration and body mass index is needed.

Little is known about the associations between sleep duration and anthropometric measures in nonwhite populations. An increased understanding of the relationships between sleep duration and anthropometric measures and measures of obesity is desirable in view of reported racial differences in sleep duration (8). Thus, our analyses among African Americans and Mexican Americans provide additional information in this area. Although associations among African Americans and Mexican Americans appeared weaker than among whites, the statistical test for interaction did not provide support for differences among these three racial or ethnic groups. In a prospective analysis of 332 African Americans and 775 Hispanic Americans aged 18–81 years, participants who slept ≤5 hours per night or ≥8 hours per night increased their body mass index to a greater extent than those who slept 6–7 hours (9). These findings suggest that additional research examining the relationships between sleep duration and measures of obesity in Hispanic populations is needed. Furthermore, research exploring racial or ethnic differences in sleep duration and how such differences relate to a host of health outcomes is also warranted.

Our analyses showed that the associations between sleep duration and anthropometric variables were stronger in younger adults compared with older adults. This effect modification by age has been reported before as demonstrated by an analysis of data from the NHANES I Epidemiologic Follow-up Study (10). In that study, the authors reported a significant association between sleep duration and body mass index among adults aged 32–49 years but not in adults who were older. Associations between sleep duration and anthropometric outcomes may conceivably be easier to demonstrate among young adults among whom potential confounders such as medical conditions, medication use, and other characteristics are of lesser concern.

Various mechanisms explain the associations between sleep duration and anthropometric measures. First, some research has suggested that energy intake is increased in short sleepers (11,12), but not all studies have found that short sleep duration is associated with increased energy intake (13,14). When short sleepers experience increased hunger and appetite (15,16), an increase in energy intake is likely. In addition, short sleepers may also modify their eating patterns and tilt towards increasing energy intake from snacks even if energy intake remains unchanged (14). Whether alterations in eating patterns towards less healthy ones even in the absence of changes in total energy intake promote weight gain and obesity deserves further exploration. Hormonal disturbances that affect hunger and appetite have been demonstrated. Thus, decreases in concentrations of leptin, which is a satiety hormone, and increases in concentrations of ghrelin, which increases hunger, have been found in short sleepers (15–19). Furthermore, sleep deprivation blunts the initial nocturnal increase in concentrations of ghrelin (18). Second, some research has also shown energy expenditure to be decreased among short sleepers (13,16) but other studies have yielded contrary findings (9)(11)(20–23). Our analyses suggested little difference in mean level of physical activity between short and normal sleepers. Thus, sleep deprivation may adversely affect the energy balance in humans leading to weight gain.

The strengths of our study feature a large nationally representative sample and the measurements of body mass index and waist circumference, but several limitations need to be acknowledged. First, the cross-sectional nature of our study precludes definitely establishing the directionality of the association. However, prospective studies have generally shown short sleep duration to be a risk factor for weight gain and obesity. Second, our estimate of sleep duration was based on a single question that asked about sleep duration during week days or work days. Thus, we were unable to consider sleep duration during weekends or nonwork days. Furthermore, because sleep duration was based on self-report, responses were subject to some degree of error. If the error was random, the likely impact on our estimates was to attenuate associations. However, some data suggest that self-reported sleep duration may be biased as adults tend to over-report their actual sleep duration (24,25). Correlations between self-reported habitual sleep duration with sleep duration measured by polysomnography or actigraphy have ranged from 0.18 to 0.47 (24,25) and with sleep duration measured by sleep diaries have been reported as high as 0.79 (26). Third, our results are subject to residual confounding although we controlled for a large set of potential confounders that included measurements of socioeconomic status, lifestyle behaviors, and comorbidities.

In conclusion, sleep duration showed an inverse linear association with anthropometric parameters, in the entire population and most demographic subgroups examined in this investigation, particularly in analyses limited to adults without depression or diagnosed sleep disorders. Although it has been generally assumed that sleep duration has shortened in the United States (27–31), a recent review concluded that results about trends in sleep duration from the 1960s on were inconsistent (32). Assuming that sleep duration is causally related to weight gain and obesity, lengthening the amount of sleep that adults get may exert beneficial effects on the future trajectory of the obesity epidemic in the United States.

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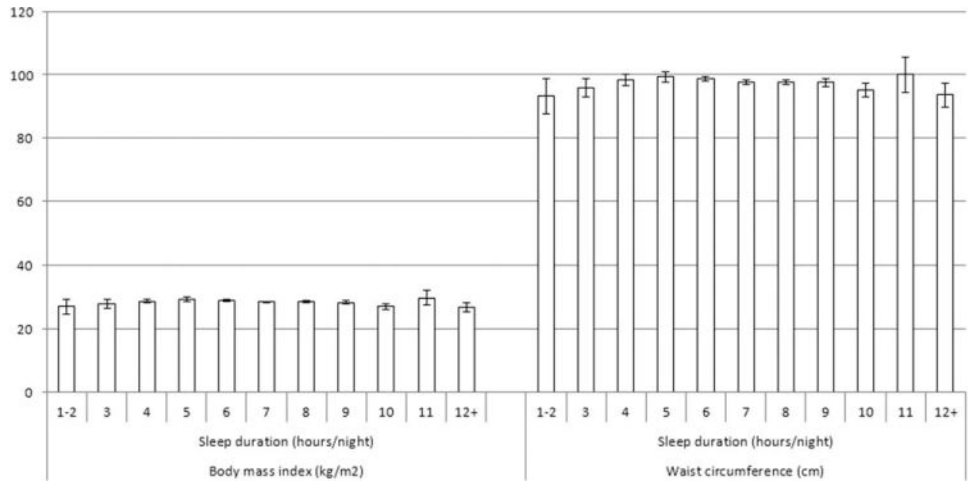

FIGURE 1.
Adjusted mean body mass index and waist circumference in function of sleep duration among 13,742 participants aged ≥20 years, National Health and Nutrition Examination Survey 2005–2010. Results were adjusted for age, gender, race or ethnicity, education, employment status, children aged ≤17 years in household, smoking status, leisure-time physical activity, alcohol use, any prescription medication use, depression score, histories of diabetes, cardiovascular disease, chronic obstructive pulmonary disease, arthritis, thyroid disease, liver disease, cancer, and sleep disorder.

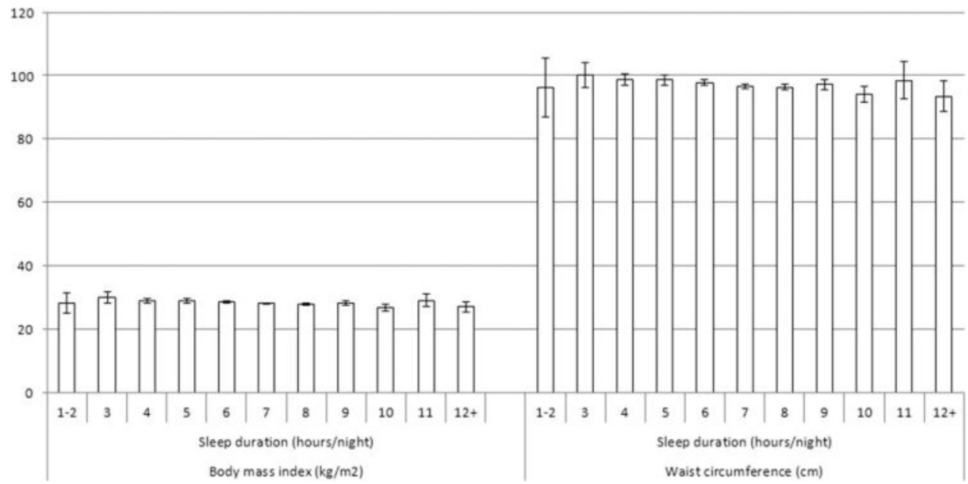

FIGURE 2.

Adjusted mean body mass index and waist circumference in function of sleep duration among 11789 participants aged ≥20 years, National Health and Nutrition Examination Survey 2005–2010. Participants with a depression score of ≥10 or reported having ever been told by a doctor or other health professional about having a sleep disorder were excluded. Results were adjusted for age, gender, race or ethnicity, education, employment status, children aged ≤17 years in household, smoking status, leisure-time physical activity, alcohol use, any prescription medication use, histories of diabetes, cardiovascular disease, chronic obstructive pulmonary disease, arthritis, thyroid disease, liver disease, and cancer.

TABLE 1

Selected age-adjusted[a] characteristics (mean or percentage [standard error]) among 13,742 participants aged ≥20 years by level of sleeping duration, National Health and Nutrition Examination Survey 2005–2010

	Sleep duration (h/night)					
	1–6 (*N* = 5408)	**7–9 (*N* = 8001)**	**10+ (*N* = 333)**	***P* 1–6 vs 7–9**	***P* 7–9 vs 10+**	***P* 1–6 vs 10+**
Age, years	46.3 (0.3)	47.0 (0.4)	48.8 (1.5)	0.026	0.263	0.112
Body mass index, kg/m^2	29.2 (0.1)	28.2 (0.1)	27.8 (0.5)	<0.001	0.365	0.003
Waist circumference, cm	99.3 (0.3)	97.1 (0.3)	96.2 (1.1)	<0.001	0.415	0.004
Weekly MET-h	15.2 (0.6)	15.9 (0.6)	10.5 (2.3)	0.272	0.023	0.064
Men, %	51.5 (0.9)	47.9 (0.6)	40.4 (3.1)	0.005	0.021	0.001
White, %	65.2 (2.2)	74.5 (1.7)	67.3 (3.9)	<0.001	0.050	0.526
≥High school graduate, %	80.4 (0.8)	82.8 (1.0)	72.3 (2.4)	0.002	<0.001	0.002
Employed, %	65.5 (0.7)	66.9 (0.7)	39.6 (4.1)	0.039	<0.001	<0.001
Children aged ≤17 years in household, %	42.9 (0.9)	41.4 (1.0)	36.7 (3.9)	0.179	0.219	0.131
Current smoker, %	27.2 (0.9)	19.2 (0.7)	35.2 (3.4)	<0.001	<0.001	0.022
Excess alcohol intake, %	8.2 (0.6)	8.9 (0.5)	14.6 (2.8)	0.318	0.038	0.016
Depression score	3.7 (0.1)	2.4 (0.1)	4.5 (0.3)	<0.001	<0.001	0.028
Any prescription medication use, %	56.7 (0.9)	55.9 (0.7)	67.3 (3.1)	0.433	0.001	<0.001
History of:						
Cardiovascular disease, %	9.6 (0.6)	6.8 (0.3)	12.0 (1.8)	<0.001	0.007	0.185
Diagnosed diabetes, %	9.0 (0.5)	6.9 (0.3)	11.0 (1.6)	<0.001	0.018	0.248
Chronic obstructive pulmonary disease, %	5.3 (0.4)	3.0 (0.3)	7.9 (1.6)	<0.001	0.005	0.131
Arthritis, %	27.6 (0.7)	22.2 (0.5)	32.6 (3.7)	<0.001	0.006	0.194
Thyroid, %	9.1 (0.5)	9.9 (0.3)	11.0 (2.0)	0.247	0.585	0.359
Liver, %	3.4 (0.4)	2.8 (0.2)	6.6 (2.0)	0.097	0.063	0.124
Cancer, %	8.7 (0.5)	9.4 (0.4)	9.7 (1.9)	0.324	0.869	0.602
Sleep disorder, %	9.7 (0.5)	5.7 (0.3)	9.5 (2.1)	<0.001	0.079	0.907

[a] Age-adjusted to the year 2000 projected US population using the direct method.

TABLE 2

Adjusted mean (standard error) body mass index, and waist circumference among 13,742 participants aged ≥20 years, by levels of sleep duration, National Health and Nutrition Examination Survey 2005–2010

	Sleep duration (h/night)						
	1–6 (*N* = 5408)	**7–9 (*N* = 8001)**	**10+ (*N* = 333)**	***P* for overall adjusted Wald *F*-test**	***P* 1–6 vs 7–9**	***P* 7–9 vs 10+**	***P* 1–6 vs 10+**
Body mass index (kg/m^2)							
Model 1[a]	29.3 (0.1)	28.2 (0.1)	27.5 (0.4)	<0.001	<0.001	0.100	<0.001
Model 2[b]	29.2 (0.1)	28.3 (0.1)	27.4 (0.4)	<0.001	<0.001	0.035	<0.001
Model 3[c]	29.2 (0.1)	28.3 (0.1)	27.5 (0.4)	<0.001	<0.001	0.052	<0.001
Model 4[d]	29.0 (0.1)	28.4 (0.1)	27.3 (0.4)	<0.001	<0.001	0.006	<0.001
Waist circumference (cm)							
Model 1[a]	99.6 (0.3)	97.2 (0.3)	95.8 (1.1)	<0.001	<0.001	0.216	0.001
Model 2[b]	99.3 (0.3)	97.4 (0.3)	96.0 (1.0)	<0.001	<0.001	0.170	0.002
Model 3[c]	99.3 (0.3)	97.4 (0.3)	96.0 (1.0)	<0.001	<0.001	0.175	0.002
Model 4[d]	98.8 (0.3)	97.7 (0.3)	95.4 (0.9)	0.001	0.002	0.023	0.001

[a] Adjusted for age.

[b] Adjusted for age, gender, race or ethnicity, and education, employment status, and children aged ≤17 years in household.

[c] Adjusted for variables in model 2 plus smoking status, leisure-time physical activity, and alcohol use.

[d] Adjusted for variables in model 3 plus any prescription medication use, depression score, histories of diabetes, cardiovascular disease, chronic obstructive pulmonary disease, arthritis, thyroid disease, liver disease, cancer, and sleep disorder.

TABLE 3

Results from linear regression analyses of anthropometric variables (dependent variable) on sleep duration (independent variable) among 13,742 participants aged ≥20 years, National Health and Nutrition Examination Survey 2005–2010

		Body mass index (kg/m^2)			Waist circumference (cm)		
Population		**Beta (SE)**	***P***	***P* interaction**	**Beta (SE)**	***P***	***P* interaction**
Total (*N = 13742)*	Model 1[a]	−0.39 (0.05)	<0.001	A	−0.90 (0.13)	<0.001	A
	Model 2[b]	−0.31 (0.05)	<0.001	A	−0.68 (0.13)	<0.001	A
	Model 3[c]	−0.33 (0.05)	<0.001	A	−0.69 (0.12)	<0.001	A
	Model 4[d]	−0.27 (0.04)	<0.001	A	−0.53 (0.11)	<0.001	A
	Model 5[e]	0.51 (0.25)	0.044	A	1.22 (0.61)	0.053	A
		−0.05 (0.02)[f]	0.005	A	−0.12 (0.05)[f]	0.013	A
Men (*N = 6904)*	Model 1[a]	−0.32 (0.06)	<0.001	0.136	−0.64 (0.17)	<0.001	0.144
	Model 2[b]	−0.28 (0.06)	<0.001	0.135	−0.62 (0.17)	0.001	0.135
	Model 3[c]	−0.31 (0.06)	<0.001	0.175	−0.68 (0.16)	<0.001	0.177
	Model 4[d]	−0.26 (0.06)	<0.001	0.206	−0.54 (0.15)	0.001	0.212
	Model 5[e]	0.48 (0.33)	0.154	A	−0.42 (0.15)	0.008	0.286
		−0.05 (0.02)[f]	0.034	A	A	A	A
Women (*N = 6838)*	Model 1[a]	−0.46 (0.07)	<0.001		−0.94 (0.18)	<0.001	
	Model 2[b]	−0.33 (0.08)	<0.001		−0.70 (0.19)	0.001	
	Model 3[c]	−0.33 (0.07)	<0.001		−0.65 (0.18)	0.001	
	Model 4[d]	−0.26 (0.07)	<0.001		−0.49 (0.16)	0.004	
	Model 5[e]	−0.17 (0.06)	0.010		−0.27 (0.16)	0.099	
White (*N = 6783)*	Model 1[a]	−0.40 (0.06)	<0.001	0.200	−1.07 (0.17)	<0.001	0.036
	Model 2[b]	−0.34 (0.06)	<0.001	0.321	−0.77 (0.16)	<0.001	0.170
	Model 3[c]	−0.36 (0.06)	<0.001	0.491	−0.77 (0.15)	<0.001	0.300
	Model 4[d]	−0.30 (0.05)	<0.001	0.540	−0.61 (0.14)	<0.001	0.336
	Model 5[e]	0.65 (0.34)	0.064	A	1.38 (0.92)	0.140	A

Population		Body mass index (kg/m²)			Waist circumference (cm)		
		Beta (SE)	*P*	*P* interaction	Beta (SE)	*P*	*P* interaction
		−0.06 (0.02)[f]	0.012	A	−0.13 (0.07)[f]	0.049	A
African American (*N = 2743)*	Model 1[a]	−0.28 (0.08)	0.002		−0.56 (0.18)	0.003	
	Model 2[b]	−0.27 (0.09)	0.004		−0.50 (0.19)	0.012	
	Model 3[c]	−0.28 (0.09)	0.003		−0.53 (0.19)	0.007	
	Model 4[d]	−0.16 (0.09)	0.073		−0.28 (0.19)	0.149	
	Model 5[e]	−0.13 (0.09)	0.160		−0.14 (0.19)	0.452	
Mexican American (*N = 2498)*	Model 1[a]	−0.21 (0.12)	0.086		−0.51 (0.29)	0.087	
	Model 2[b]	−0.21 (0.12)	0.072		−0.47 (0.29)	0.117	
	Model 3[c]	−0.22 (0.12)	0.077		−0.49 (0.32)	0.130	
	Model 4[d]	−0.21 (0.12)	0.098		−0.45 (0.31)	0.151	
	Model 5[e]	−0.17 (0.12)	0.174		−0.36 (0.29)	0.225	
Age 20–39 y (*N = 4544)*	Model 1[a]	−0.54 (0.08)	<0.001	0.009	−1.28 (0.18)	<0.001	0.001
	Model 2[b]	−0.46 (0.07)	<0.001	0.005	−1.08 (0.17)	<0.001	0.004
	Model 3[c]	−0.48 (0.07)	<0.001	0.001	−1.13 (0.16)	<0.001	0.002
	Model 4[d]	−0.43 (0.07)	<0.001	A	−1.01 (0.16)	<0.001	A
	Model 5[e]	−0.36 (0.07)	<0.001	A	−0.83 (0.16)	<0.001	A
Age 40–59 y (*N = 4604)*	Model 1[a]	−0.29 (0.08)	0.001		−0.74 (0.21)	0.001	
	Model 2[b]	−0.21 (0.09)	0.020		−0.44 (0.21)	0.041	
	Model 3[c]	−0.21 (0.08)	0.012		−0.39 (0.19)	0.048	
	Model 4[d]	0.94 (0.37)	0.014		−.66 (0.90)	0.005	
		−0.08 (0.03)[f]	0.005		−0.21 (0.07)[f]	0.003	
	Model 5[e]	1.49 (0.39)	<0.001		3.87 (0.87)	<0.001	
		−0.12 (0.03)[f]	<0.001		−0.29 (0.07)[f]	<0.001	
Age 60+ y (*N = 4594)*	Model 1[a]	−0.25 (0.06)	<0.001		−0.40 (0.18)	0.030	
	Model 2[b]	−0.22 (0.06)	0.001		−0.42 (0.18)	0.023	
	Model 3[c]	−0.22 (0.06)	0.000		−0.39 (0.17)	0.028	

Population	Body mass index (kg/m²)			Waist circumference (cm)		
	Beta (SE)	*P*	*P* interaction	Beta (SE)	*P*	*P* interaction
Model 4[d]	−0.18 (0.06)	0.002		−0.28 (0.16)	0.084	
Model 5[e]	−0.11 (0.06)	0.059		−0.11 (0.17)	0.520	

[a] Adjusted for age.

[b] Adjusted for age, gender, race or ethnicity, and education, employment status, and children aged ≤17 years in household.

[c] Adjusted for variables in model 2 plus smoking status, leisure-time physical activity, and alcohol use.

[d] Adjusted for variables in model 3 plus any prescription medication use, histories of diabetes, cardiovascular disease, chronic obstructive pulmonary disease, arthritis, thyroid disease, liver disease, and cancer.

[e] Adjusted for variables in model 4 plus depression score, history of sleep disorder, and, if significant, a squared term for sleep duration.

[f] Beta (SE) and *P*-value for squared term for sleep duration.

TABLE 4

Results from linear regression analyses of anthropometric variables on sleep duration among 11,789 participants aged ≥20 years, National Health and Nutrition Examination Survey 2005–2010.

		Body mass index (kg/m^2)			Waist circumference (cm)		
Population		**Beta (SE)**	***P***	***P* interaction**	**Beta (SE)**	***P***	***P* interaction**
Total (*N* = 11789)	Model 1[a]	−0.40 (0.06)	<0.001		−0.92 (0.15)	<0.001	
	Model 2[b]	−0.33 (0.06)	<0.001		−0.68 (0.15)	<0.001	
	Model 3[c]	−0.34 (0.05)	<0.001		−0.70 (0.14)	<0.001	
	Model 4[d]	−0.30 (0.05)	<0.001		−0.60 (0.13)	<0.001	
Men (*N* = 6024)	Model 1[a]	−0.33 (0.07)	<0.001	0.143	−0.64 (0.17)	0.001	0.215
	Model 2[b]	−0.28 (0.07)	<0.001	0.112	−0.60 (0.17)	0.001	0.134
	Model 3[c]	−0.31 (0.07)	<0.001	0.170	−0.66 (0.17)	<0.001	0.184
	Model 4[d]	−0.28 (0.06)	<0.001	0.174	−0.57 (0.16)	0.001	0.184
Women (*N* = 5765)	Model 1[a]	−0.47 (0.08)	<0.001		−0.89 (0.21)	<0.001	
	Model 2[b]	−0.36 (0.08)	<0.001		−0.72 (0.21)	0.001	
	Model 3[c]	−0.36 (0.08)	<0.001		−0.71 (0.20)	0.001	
	Model 4[d]	−0.31 (0.08)	<0.001		−0.60 (0.19)	0.003	
Whites (*N* = 5808)	Model 1[a]	−0.39 (0.07)	<0.001	0.441	−1.05 (0.19)	<0.001	0.235
	Model 2[b]	−0.32 (0.07)	<0.001	0.549	−0.69 (0.19)	0.001	0.562
	Model 3[c]	−0.34 (0.07)	<0.001	0.723	−0.70 (0.17)	<0.001	0.698
	Model 4[d]	−0.29 (0.06)	<0.001	0.856	−0.59 (0.17)	0.001	0.889
African Americans (*N* = 2342)	Model 1[a]	−0.41 (0.10)	<0.001		−0.86 (0.22)	<0.001	
	Model 2[b]	−0.42 (0.10)	<0.001		−0.82 (0.23)	0.001	
	Model 3[c]	−0.41 (0.10)	<0.001		−0.83 (0.23)	0.001	
	Model 4[d]	−0.35 (0.10)	0.001		−0.71 (0.22)	0.003	
Mexican Americans (*N* = 2192)	Model 1[a]	−0.23 (0.12)	0.068		−0.51 (0.30)	0.101	
	Model 2[b]	−0.24 (0.11)	0.042		−0.47 (0.30)	0.126	

Population		Body mass index (kg/m²)			Waist circumference (cm)		
		Beta (SE)	*P*	*P* interaction	Beta (SE)	*P*	*P* interaction
	Model 3[c]	−0.26 (0.12)	0.043		−0.51 (0.33)	−0.506	
	Model 4[d]	−0.25 (0.12)	0.044		−0.51 (0.32)	0.115	
Age 20–39 y (*N* = 4020)	Model 1[a]	−0.56 (0.09)	<0.001	0.004	−1.36 (0.23)	<0.001	0.001
	Model 2[b]	−0.48 (0.09)	<0.001	0.004	−1.13 (0.22)	<0.001	0.007
	Model 3[c]	−0.49 (0.09)	<0.001	0.002	−1.17 (0.21)	<0.001	0.004
	Model 4[d]	−0.46 (0.08)	<0.001	0.001	−1.08 (0.21)	<0.001	0.001
Age 40–59 y (*N* = 3779)	Model 1[a]	−0.35 (0.11)	0.003		−0.84 (0.28)	0.004	
	Model 2[b]	−0.28 (0.12)	0.023		−0.50 (0.27)	0.071	
	Model 3[c]	−0.28 (0.11)	0.016		−0.47 (0.25)	0.066	
	Model 4[d]	−0.22 (0.10)	0.033		−0.33 (0.24)	0.165	
Age 60+ y (*N* = 3990)	Model 1[a]	−0.17 (0.06)	0.014		−0.22 (0.17)	0.186	
	Model 2[b]	−0.14 (0.06)	0.031		−0.23 (0.17)	0.192	
	Model 3[c]	−0.16 (0.07)	0.021		−0.23 (0.18)	0.196	
	Model 4[d]	−0.12 (0.06)	0.062		−0.12 (0.16)	0.482	

Participants with a depression score of ≥10 or who reported having ever been told by a doctor or other health professional about having a sleep disorder were excluded.

[a] Adjusted for age.

[b] Adjusted for age, gender, race or ethnicity, and education, employment status, and children aged <=17 years in household.

[c] Adjusted for variables in model 2 plus smoking status, leisure-time physical activity, and alcohol use.

[d] Adjusted for variables in model 3 plus any prescription medication use, histories of diabetes, cardiovascular disease, chronic obstructive pulmonary disease, arthritis, thyroid disease, liver disease, and cancer.

TABLE 5

Adjusted prevalence ratios (95% confidence interval) for associations between sleep duration and general and abdominal obesity among 13,742 participants aged ≥20 years, National Health and Nutrition Examination Survey 2005–2010

		General obesity (body mass index ≥30 kg/m^2)				Abdominal obesity (waist circumference ≥102 cm in men, ≥88 cm in women)			
		Sleep duration (hours/night)				Sleep duration (hours/night)			
Population		**1–6**	**7–9**	**10+**	***P* interaction**	**1–6**	**7–9**	**10+**	***P* interaction**
Total (*N* = 13742)	Model 1[a]	1.20 (1.13, 1.28)	1.00	0.87 (0.70, 1.08)		1.10 (1.05, 1.15)	1.00	0.96 (0.85, 1.08)	
	Model 2[b]	1.15 (1.09, 1.22)	1.00	0.83 (0.67, 1.02)		1.10 (1.06, 1.16)	1.00	0.94 (0.83, 1.07)	
	Model 3[c]	1.16 (1.10, 1.23)	1.00	0.83 (0.67, 1.02)		1.10 (1.05, 1.15)	1.00	0.93 (0.82, 1.06)	
	Model 4[d]	1.10 (1.03, 1.16)	1.00	0.78 (0.64, 0.96)		1.07 (1.02, 1.11)	1.00	0.90 (0.80, 1.01)	
Men (*N* = 6904)	Model 1[a]	1.21 (1.10, 1.33)	1.00	0.84 (0.61, 1.16)	0.969	1.12 (1.03, 1.21)	1.00	0.85 (0.66, 1.10)	0.717
	Model 2[b]	1.19 (1.07, 1.31)	1.00	0.83 (0.60, 1.14)	0.960	1.12 (1.04, 1.22)	1.00	0.88 (0.68, 1.14)	0.766
	Model 3[c]	1.21 (1.09, 1.33)	1.00	0.82 (0.59, 1.14)	0.905	1.13 (1.05, 1.23)	1.00	0.87 (0.67, 1.13)	0.694
	Model 4[d]	1.15 (1.04, 1.26)	1.00	0.76 (0.57, 1.02)	0.795	1.10 (1.02, 1.18)	1.00	0.82 (0.65, 1.04)	0.478
Women (*N* = 6838)	Model 1[a]	1.20 (1.11, 1.30)	1.00	0.88 (0.66, 1.18)		1.12 (1.06, 1.18)	1.00	0.99 (0.86, 1.14)	
	Model 2[b]	1.11 (1.03, 1.21)	1.00	0.82 (0.63, 1.07)		1.08 (1.02, 1.14)	1.00	0.95 (0.82, 1.09)	
	Model 3[c]	1.12 (1.03, 1.21)	1.00	0.82 (0.64, 1.05)		1.07 (1.02, 1.13)	1.00	0.94 (0.82, 1.07)	
	Model 4[d]	1.05 (0.97, 1.14)	1.00	0.80 (0.62, 1.03)		1.04 (0.99, 1.10)	1.00	0.92 (0.81, 1.06)	
White (*N* = 6783)	Model 1[a]	1.18 (1.09, 1.27)	1.00	0.82 (0.61, 1.09)	0.090	1.11 (1.05, 1.17)	1.00	0.92 (0.78, 1.10)	0.687
	Model 2[b]	1.15 (1.06, 1.24)	1.00	0.79 (0.60, 1.05)	0.111	1.10 (1.04, 1.16)	1.00	0.90 (0.75, 1.07)	0.777
	Model 3[c]	1.16 (1.07, 1.25)	1.00	0.77 (0.59, 1.02)	0.093	1.10 (1.04, 1.16)	1.00	0.89 (0.75, 1.05)	0.801
	Model 4[d]	1.09 (<1.00, 1.18)	1.00	0.72 (0.55, 0.93)	0.130	1.06 (1.01, 1.12)	1.00	0.85 (0.72, ⟩1.00)	0.855
African American (*N* = 2743)	Model 1[a]	1.08 (0.99, 1.18)	1.00	0.74 (0.49, 1.11)		1.08 (1.00, 1.16)	1.00	0.85 (0.66, 1.10)	
	Model 2[b]	1.09 (1.00, 1.18)	1.00	0.74 (0.49, 1.13)		1.09 (1.02, 1.17)	1.00	0.85 (0.68, 1.07)	
	Model 3[c]	1.09 (1.01, 1.19)	1.00	0.77 (0.52, 1.14)		1.10 (1.02, 1.18)	1.00	0.86 (0.69, 1.07)	
	Model 4[d]	1.06 (0.97, 1.15)	1.00	0.77 (0.52, 1.15)		1.07 (<1.00, 1.16)	1.00	0.85 (0.69, 1.05)	
Mexican American (*N* = 2498)	Model 1[a]	1.18 (1.07, 1.30)	1.00	1.21 (0.87, 1.70)		1.09 (0.99, 1.19)	1.00	1.10 (0.81, 1.49)	

Population		General obesity (body mass index ≥30 kg/m^2)				Abdominal obesity (waist circumference ≥102 cm in men, ≥88 cm in women)			
		Sleep duration (hours/night)				Sleep duration (hours/night)			
		1–6	7–9	10+	***P* interaction**	1–6	7–9	10+	***P* interaction**
	Model 2[b]	1.16 (1.06, 1.28)	1.00	1.16 (0.84, 1.59)		1.07 (0.99, 1.17)	1.00	0.99 (0.74, 1.33)	
	Model 3[c]	1.17 (1.06, 1.29)	1.00	1.16 (0.86, 1.56)		1.08 (0.99, 1.17)	1.00	0.98 (0.74, 1.31)	
	Model 4[d]	1.14 (1.03, 1.25)	1.00	1.11 (0.82, 1.49)		1.06 (0.98, 1.15)	1.00	0.96 (0.73, 1.26)	
Age 20–39 y (*N* = 4544)	Model 1[a]	1.28 (1.16, 1.41)	1.00	0.93 (0.60, 1.47)	0.148	1.19 (1.09, 1.30)	1.00	1.00 (0.73, 1.37)	0.133
	Model 2[b]	1.21 (1.10, 1.32)	1.00	0.91 (0.57, 1.44)	0.139	1.17 (1.08, 1.27)	1.00	0.98 (0.72, 1.35)	0.120
	Model 3[c]	1.24 (1.13, 1.36)	1.00	0.93 (0.58, 1.47)	0.036	1.19 (1.10, 1.29)	1.00	0.99 (0.72, 1.36)	0.044
	Model 4[d]	1.16 (1.05, 1.28)	1.00	0.86 (0.54, 1.35)	0.018	1.14 (1.05, 1.24)	1.00	0.95 (0.69, 1.30)	0.030
Age 40–59 y (*N* = 4604)	Model 1[a]	1.18 (1.07, 1.29)	1.00	0.64 (0.39, 1.06)		1.06 (1.00, 1.13)	1.00	0.89 (0.66, 1.21)	
	Model 2[b]	1.14 (1.04, 1.25)	1.00	0.59 (0.36, 0.99)		1.07 (1.00, 1.14)	1.00	0.82 (0.61, 1.12)	
	Model 3[c]	1.14 (1.04, 1.24)	1.00	0.58 (0.37, 0.93)		1.06 (1.00, 1.13)	1.00	0.82 (0.61, 1.09)	
	Model 4[d]	1.08 (0.99, 1.18)	1.00	0.56 (0.35, 0.89)		1.03 (0.97, 1.09)	1.00	0.78 (0.60, 1.03)	
Age 60+ y (*N* = 4594)	Model 1[a]	1.11 (1.01, 1.22)	1.00	1.03 (0.77, 1.37)		1.06 (1.00, 1.13)	1.00	1.04 (0.89, 1.21)	
	Model 2[b]	1.08 (0.99, 1.19)	1.00	0.99 (0.75, 1.30)		1.07 (1.01, 1.14)	1.00	1.03 (0.89, 1.19)	
	Model 3[c]	1.07 (0.98, 1.17)	1.00	0.96 (0.74, 1.25)		1.07 (1.00, 1.13)	1.00	1.01 (0.88, 1.17)	
	Model 4[d]	1.03 (0.94, 1.12)	1.00	0.90 (0.68, 1.19)		1.05 (0.99, 1.11)	1.00	0.98 (0.85, 1.14)	

[a] Adjusted for age.

[b] Adjusted for age, gender, race or ethnicity, education, employment status, and children aged ≤17 years in household.

[c] Adjusted for variables in model 2 plus smoking status, leisure-time physical activity, and alcohol use.

[d] Adjusted for variables in model 3 plus any prescription medication use, depression score, histories of diabetes, cardiovascular disease, chronic obstructive pulmonary disease, arthritis, thyroid disease, liver disease, cancer, and sleep disorder.