ORIGINAL RESEARCH

Habitual Sleep Duration and Predicted 10-Year Cardiovascular Risk Using the Pooled Cohort Risk Equations Among US Adults

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***Background*—**The association between sleep duration and predicted cardiovascular risk has been poorly characterized. The objective of this study was to examine the association between self-reported sleep duration and predicted 10-year cardiovascular risk among US adults.

***Methods and Results*—**Data from 7690 men and nonpregnant women who were aged 40 to 79 years, who were free of self-reported heart disease and stroke, and who participated in a National Health and Nutrition Examination Survey from 2005 to 2012 were analyzed. Sleep duration was self-reported. Predicted 10-year cardiovascular risk was calculated using the pooled cohort equations. Among the included participants, 13.1% reported sleeping ≤5 hours, 24.4% reported sleeping 6 hours, 31.9% reported sleeping 7 hours, 25.2% reported sleeping 8 hours, 4.0% reported sleeping 9 hours, and 1.3% reported sleeping ≥10 hours. After adjustment for covariates, geometric mean–predicted 10-year cardiovascular risk was 4.0%, 3.6%, 3.4%, 3.5%, 3.7%, and 3.7% among participants who reported sleeping ≤5, 6, 7, 8, 9, and ≥10 hours per night, respectively ($P_{\text{Wald chi-square}}<0.001$). The age-adjusted percentages of predicted cardiovascular risk ≥20% for the 6 intervals of sleep duration were 14.5%, 11.9%, 11.0%, 11.4%, 11.8%, and 16.3% ($P_{\text{Wald chi-square}}=0.022$). After maximal adjustment, however, sleep duration was not significantly associated with cardiovascular risk ≥20% ($P_{\text{Wald chi-square}}=0.698$).

***Conclusions*—**Mean-predicted 10-year cardiovascular risk was lowest among adults who reported sleeping 7 hours per night and increased as participants reported sleeping fewer and more hours. **(*J Am Heart Assoc*. 2014;3:e001454 doi: 10.1161/JAHA.114.001454)**

Key Words: cardiovascular disease risk factors • epidemiology • population • prevention • sleep

The possible benefits of adequate sleep in maintaining cardiovascular health are increasingly being recognized. Because cardiovascular disease continues to be a leading cause of morbidity and mortality in the United States, understanding how the many aspects of sleep health relate to cardiovascular disease can help formulate new approaches to the prevention and control of this disease. In 2011, a meta-analysis of prospective studies of sleep duration and cardiovascular disease showed an increased risk for coronary heart disease and stroke with both short and long duration of sleep.[1]

Although studies have examined associations between sleep duration and various cardiovascular risk factors included in the risk equations,[2–13] an aspect of the study of sleep duration and cardiovascular health that has been overlooked is the relationship between sleep duration and predicted cardiovascular risk. Beginning with the Framingham risk equations, a succession of risk scores to assess future cardiovascular risk—typically projecting 10 years ahead—have been introduced into clinical practice. Recently, a new set of cardiovascular risk equations has been introduced in the United States.[14] Because the potential association between sleep duration and predicted cardiovascular risk remains ill defined, the objective of this study was to examine how 10-year predicted cardiovascular risk varies as a function of sleep duration among adults in the United States.

Methods

Four 2-year cycles of data from the National Health and Nutrition Examination Survey (NHANES) 2005–2012 were

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included in this analysis.[15] Using a multistage, stratified sampling design, every 2-year cycle includes a national sample representative of the civilian, noninstitutionalized US population. After providing informed consent, participants were interviewed in their homes. Those who attended a mobile examination center completed additional questionnaires, had various examinations, and provided a blood sample. Interview and examination response rates for each 2-year cycle exceeded 70%. The surveys received approval from the National Center for Health Statistics Research ethics review board, and participants in the surveys provided informed consent.

Of the 12 785 men and nonpregnant women aged 40 to 79 years who attended the mobile examination center, 11 023 participants were free of self-reported cardiovascular disease. Predicted cardiovascular risk could be calculated for 9988 of these participants, and 11 007 participants provided information about their sleep duration. After excluding participants who were using cholesterol-lowering medications, the sample size was reduced to 8675 participants, of whom 7690 with complete data for all study variables were included in the analyses. The participants included 3746 men (48.7%), 3944 women (51.3%), 3487 white participants (45.3%), 1624 black participants (21.1%), 1302 Mexican American participants (16.9%), and 1277 of another race or ethnicity (16.6%). The mean age of this sample was 54.6 years.

Predicted 10-year cardiovascular risk for adults aged 40 to 79 years was calculated using the pooled cohort equations for estimation of 10-year risk for atherosclerotic cardiovascular disease developed by the American College of Cardiology/American Heart Association (ACC/AHA) Task Force on Practice Guidelines.[14] Separate equations for white and black men and women were developed and included the following set of variables: age, concentrations of total cholesterol and high-density lipoprotein cholesterol, treated and untreated systolic blood pressure, diabetes status, and smoking status. Participants who reported that 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 were excluded from the analyses. Participants with risks of $<$7.5% and $\geq$20% were considered to be at low and high risk, respectively, for future cardiovascular events.[16]

Concentrations of total cholesterol and concentrations of high-density lipoprotein cholesterol, after precipitation with magnesium and dextran sulfate, were measured with an enzymatic method on Hitachi 717 and 912 analyzers (Hitachi Global Storage Technologies) during the period 2005–2006 and on Roche Modular P chemistry analyzers (Roche Diagnostics) during 2007–2012. Systolic blood pressure measurements consisted of the average of the last 2 measurements of blood pressure for participants who had 3 measurements, the last measurement for participants with only 2 measurements, and the only measurement for participants who had 1 measurement. Blood pressure treatment status was determined from the question, "Are you now taking prescribed medicine?" Participants were considered to have diabetes if they responded affirmatively to the question, "Have you ever been told by a doctor or health professional you have diabetes or sugar diabetes?" or if they had a concentration of glycated hemoglobin (HbA1c) $\geq$6.5%. Concentrations of HbA1c were measured by high-performance liquid chromatography on a Tosoh A1c 2.2 Plus glycohemoglobin analyzer (2005–2006), a Tosoh G7 HPLC analyzer (2007–2012), and a Tosoh G8 HPLC analyzer (2011–2012) (Tosoh Medics, Inc). Participants who reported that they had smoked $\geq$100 cigarettes during their lifetime and were still smoking were defined as being current smokers. Those who had smoked $\geq$100 cigarettes during their lifetime but had stopped were defined as being former smokers. Participants who had smoked $<$100 cigarettes during their lifetime were defined as having never smoked.

Sleep duration was assessed with the question, "How much sleep do you usually get at night on weekdays or workdays?" Answers ranged from 1 hour to 12 hours per night in whole hours. Answers of $>$12 hours were available only as a category of $\geq$12 hours. To examine the shape of the association between sleep duration and cardiovascular risk in as much detail as sample size allowed, the following 6 categories of sleeping duration were established for the analyses: $\leq$5, 6, 7, 8, 9, and $\geq$10 hours per night.

The following covariates were included in the analyses: age, sex, race or ethnicity (white, black, Mexican American, and other), educational status (less than high school graduate, high school graduate or equivalent, more than high school), leisure-time physical activity, body mass index, and histories of chronic obstructive pulmonary disease, arthritis, liver disease, thyroid problems, cancer, and sleep disorders. For the years 2005 and 2006, leisure-time physical activity as a weekly metabolic equivalent (MET) -hours index was estimated by summing the product of weekly time spent in each activity multiplied by the MET value for that activity. One MET is the energy expenditure of $\approx$1 kcal/kg body weight per hour. Owing to changes in the physical activity questionnaire for the years 2007–2012, weekly MET-hours for moderate and vigorous activities were estimated from questions that asked participants about their participation in moderate and vigorous activities, the number of days per week they engaged in these activities, and the number of minutes engaged in these activities on a typical day. Body mass index was calculated from measured height and weight. Participants who responded that they still had chronic bronchitis or ever had emphysema were defined as having chronic obstructive pulmonary disease. Participants with arthritis, liver disease, thyroid problems, and cancer were identified from the

questions, "Has a doctor or other health professional ever told you that you had . . . arthritis/any kind of liver condition/thyroid problem/cancer or a malignancy of any kind?" The presence of a sleep disorder was inferred from the question, "Have you ever been told by a doctor or other health professional that you have a sleep disorder?"

The analyses, which included 8 years of pooled data, were limited to men and nonpregnant women who were aged 40 to 79 years and free of self-reported cardiovascular disease. Participants who reported taking prescribed medicine to lower blood cholesterol were excluded. Predicted cardiovascular risk was log-transformed. The statistical significance of the associations between continuous variables and categories of sleep duration was tested with linear regression analysis. Statistical significance of associations between dichotomous variables and categories of sleep duration was tested with log-linear analysis. Least-squares adjusted mean-predicted cardiovascular risk was calculated by using analysis of covariance. Analyses were conducted with SUDAAN (RTI International) to account for the complex survey design, and sampling weights were used to calculate estimates (means, percentages, regression coefficients, and prevalence ratios). Statistical significance was defined as $P<0.05$.

Table 1. Unadjusted Mean or Percent (SE) of Selected Factors Among Adults Aged 40 to 79 Years Who Were Free of Self-Reported Cardiovascular Disease by Sleep Duration, National Health and Nutrition Examination Survey 2005–2012

	Habitual Sleep Duration (Hours per Night)						
	≤5	6	7	8	9	≥10	$P_{\text{Wald F or chi-square}}$
n	1230	1921	2174	1934	304	127	—
Age, y	52.2 (0.3)	52.8 (0.3)	53.2 (0.3)	54.0 (0.4)	55.1 (0.9)	55.2 (1.2)	<0.001
Men, %	47.8 (1.8)	53.1 (1.6)	47.3 (1.3)	43.5 (1.7)	34.6 (3.2)	35.8 (5.5)	<0.001
White race, %	59.3 (2.9)	70.4 (2.0)	79.4 (1.4)	75.9 (1.8)	80.6 (2.5)	70.8 (4.6)	<0.001
High school graduate or higher, %	77.9 (1.6)	83.8 (1.2)	86.1 (0.9)	83.8 (1.0)	79.4 (2.7)	71.1 (4.3)	<0.001
Total cholesterol, mg/dL	209.9 (1.5)	207.5 (1.4)	209.0 (0.9)	211.6 (1.5)	213.2 (3.1)	204.8 (3.9)	0.136
High-density lipoprotein cholesterol, mg/dL	54.2 (0.7)	53.4 (0.6)	55.4 (0.4)	56.2 (0.6)	56.0 (1.0)	55.4 (2.2)	0.011
Systolic blood pressure, mm Hg	124.9 (0.6)	123.2 (0.5)	122.4 (0.5)	123.3 (0.5)	123.7 (1.2)	123.9 (1.6)	0.064
HbA1c, %	5.7 (<0.1)	5.6 (<0.1)	5.5 (<0.1)	5.6 (<0.1)	5.6 (<0.1)	5.6 (0.1)	<0.001
Leisure-time physical activity, MET-h/week	8.3 (0.6)	13.2 (0.9)	14.7 (0.7)	14.4 (0.7)	13.2 (2.5)	12.0 (3.8)	<0.001
Body mass index, kg/m^2	29.5 (0.3)	29.1 (0.2)	28.4 (0.1)	28.3 (0.2)	28.9 (0.5)	28.9 (0.9)	0.008
Current smoker, %	31.9 (1.9)	22.3 (1.3)	16.9 (1.0)	16.9 (1.1)	24.7 (3.5)	37.5 (5.4)	<0.001
Current use of antihypertensive medications, %	22.4 (1.4)	21.3 (1.0)	19.8 (1.0)	20.3 (1.1)	17.8 (2.7)	19.3 (3.8)	0.313
Diabetes, %	10.6 (1.2)	10.3 (0.9)	6.4 (0.6)	9.4 (0.7)	7.1 (1.4)	11.3 (3.0)	<0.001
Medical history							
Chronic obstructive pulmonary disease, %	6.4 (1.0)	3.9 (0.7)	2.0 (0.4)	3.3 (0.5)	2.5 (0.8)	8.0 (3.0)	<0.001
Arthritis, %	38.6 (2.0)	26.4 (1.8)	25.9 (1.2)	26.9 (1.4)	23.4 (2.6)	41.1 (5.4)	<0.001
Thyroid, %	9.9 (0.9)	9.4 (0.9)	12.2 (0.9)	12.1 (1.0)	10.7 (2.4)	14.5 (3.0)	0.095
Liver, %	5.0 (0.9)	4.3 (0.7)	3.4 (0.5)	4.1 (0.5)	3.4 (1.3)	7.9 (3.2)	0.385
Cancer, %	8.1 (0.9)	8.2 (0.8)	8.9 (0.6)	11.4 (1.1)	12.8 (2.2)	10.1 (3.7)	0.073
Sleep disorder, %	16.7 (1.5)	7.3 (0.8)	6.7 (0.7)	6.1 (0.9)	10.5 (2.9)	9.0 (3.0)	<0.001
Mean 10-year risk, %	7.1 (0.2)	7.0 (0.3)	6.2 (0.2)	7.4 (0.3)	8.2 (0.7)	9.2 (1.1)	<0.001
Mean 10-year risk, %*	4.0 (0.2)	3.8 (0.2)	3.2 (0.1)	3.5 (0.2)	3.8 (0.4)	4.4 (0.7)	0.004
10-year risk, %							
<7.5	70.2 (1.9)	69.0 (1.7)	74.0 (1.2)	69.6 (1.5)	63.9 (3.8)	62.0 (6.0)	—
7.5 to <20	22.5 (1.8)	23.5 (1.4)	19.8 (0.9)	21.3 (1.1)	24.8 (3.1)	21.4 (4.3)	—
≥20	7.2 (0.8)	7.5 (0.8)	6.2 (0.6)	9.1 (0.8)	11.4 (1.7)	16.6 (3.8)	<0.001

MET-h indicates metabolic equivalent hours. HbA1c indicates glycated hemoglobin.
*Geometric mean.

Results

Among the included participants, 13.1% (SE 0.6) reported sleeping ≤5 hours, 24.4% (SE 0.6) reported sleeping 6 hours, 31.9% (SE 0.7) reported sleeping 7 hours, 25.2% (SE 0.6) reported sleeping 8 hours, 4.0% (SE 0.3) reported sleeping 9 hours, and 1.3% (SE 0.1) reported sleeping ≥10 hours. Mean-predicted cardiovascular risk was 6.9% (SE 0.1). Furthermore, 70.6% (SE 0.7) of participants had a cardiovascular risk <7.5%, 21.7% (SE 0.6) had a risk 7.5% to <20%, and 7.7% (SE 0.3) had a risk ≥20%.

Mean age increased by 3 years across categories of sleep duration (Table 1). With the exception of mean concentrations of total cholesterol and the percentage of participants who reported using antihypertensive medications, the other cardiovascular disease risk factors varied significantly across categories of sleep duration.

Crude mean-predicted 10-year cardiovascular risk showed a curvilinear association with sleep duration with the lowest mean risk occurring among those who reported sleeping 7 hours per night (6.2%) and the highest risk among those who reported sleeping ≥10 hours per night (9.2%) ($P_{\text{Wald F test}}<0.001$) (Table 1). Because mean age varied considerably by sleep duration and because age is a powerful determinant of risk, age-adjusted risk was also calculated. Although the nonlinearity of the relationship remained after age-adjustment ($P_{\text{Wald F test}}<0.001$), the differences in cardiovascular risk among sleep-duration categories were attenuated. The maximally adjusted geometric mean-predicted 10-year cardiovascular risk was 4.0%, 3.6%, 3.4%, 3.5%, 3.7%, and 3.7% among participants who reported sleeping ≤5, 6, 7, 8, 9, and ≥10 hours per night, respectively ($P_{\text{Wald F test}}<0.001$) (Table 2). Using 7 hours as the reference category, the differences in mean cardiovascular risk between ≤5 and 6 hours and the referent category were statistically significant.

The unadjusted percentages of adults with a predicted 10-year cardiovascular risk ≥20% were 7.2%, 7.5%, 6.2%, 9.1%, 11.4%, and 16.6% among participants who reported sleeping ≤5, 6, 7, 8, 9, and ≥10 hours per night, respectively (Table 3). Direct age adjustment modified these estimates substantially. In unadjusted models, participants who slept 8, 9, and ≥10 hours all had elevated prevalence ratios compared with participants who slept 7 hours (Table 3). After maximal adjustment, sleep duration was no longer significantly associated with cardiovascular risk ≥20% ($P_{\text{Wald chi-square}}=0.698$).

Table 2. Geometric Mean Unadjusted and Adjusted Predicted 10-Year Cardiovascular Risk Among Adults Aged 40 to 79 Years Who Were Free of Self-Reported Cardiovascular Disease by Sleep Duration, National Health and Nutrition Examination Survey 2005–2012

	Habitual Sleep Duration (Hours per Night)						
	≤5	6	7	8	9	≥10	$P_{\text{Wald F}}$
n	1230	1921	2174	1934	304	127	—
Model 1	4.0 (0.2)	3.8 (0.2)	3.2 (0.1)	3.5 (0.2)	3.8 (0.4)	4.4 (0.7)	0.004
Model 2	4.4 (0.1)	3.9 (0.1)	3.2 (0.1)	3.3 (0.1)	3.2 (0.2)	3.7 (0.4)	<0.001
Model 3	4.0 (0.1)	3.6 (0.1)	3.4 (0.0)	3.5 (0.1)	3.7 (0.2)	3.7 (0.4)	<0.001
Model 4	3.5 (0.1)	3.5 (0.1)	3.4 (0.1)	3.7 (0.1)	4.4 (0.4)	4.0 (0.5)	0.047
Men							
n	606	992	1043	923	123	59	—
Model 1	6.2 (0.3)	5.8 (0.3)	5.3 (0.2)	6.1 (0.3)	8.2 (1.0)	7.8 (1.5)	0.004
Model 2	6.8 (0.3)	6.1 (0.2)	5.3 (0.1)	5.8 (0.2)	6.2 (0.5)	6.0 (0.5)	<0.001
Model 3	6.3 (0.3)	6.0 (0.2)	5.5 (0.1)	5.9 (0.2)	6.1 (0.4)	5.5 (0.5)	0.060
Model 4	5.5 (0.3)	5.8 (0.3)	5.5 (0.2)	6.3 (0.3)	8.2 (1.0)	6.6 (1.1)	0.004
Women							
n	624	929	1131	1011	181	68	—
Model 1	2.7 (0.1)	2.3 (0.1)	2.1 (0.1)	2.3 (0.1)	2.5 (0.3)	3.2 (0.7)	0.015
Model 2	3.0 (0.2)	2.3 (0.1)	2.1 (0.1)	2.1 (0.1)	2.4 (0.1)	2.8 (0.4)	<0.001
Model 3	2.7 (0.1)	2.3 (0.1)	2.2 (0.0)	2.2 (0.1)	2.4 (0.1)	2.6 (0.3)	0.021
Model 4	2.3 (0.1)	2.3 (0.1)	2.2 (0.1)	2.3 (0.1)	2.7 (0.3)	2.5 (0.4)	0.742

Model 1 is unadjusted. Model 2 is adjusted for age. Model 3 is adjusted for age; sex (except sex-specific models); race or ethnicity; educational status; leisure-time physical activity; body mass index; and histories of arthritis, cancer, chronic obstructive pulmonary disease, liver condition, thyroid problems, and sleep disorders. Model 4 is adjusted for all variables in Model 3 except age.

Table 3. Prevalence (SE) of Predicted 10-Year Cardiovascular Risk ≥20% and Prevalence Ratios (95% CI) for Associations of Between Sleep Duration and Cardiovascular Risk Among Adults Aged 40 to 79 Years Who Were Free of Self-Reported Cardiovascular Disease, National Health and Nutrition Examination Survey 2005–2012

	Habitual Sleep Duration (Hours per Night)						P_{Wald} chi-square
	≤5	6	7	8	9	≥10	
Total							
n	1230	1921	2174	1934	304	127	
Prevalence, unadjusted, %	7.2 (0.8)	7.5 (0.8)	6.2 (0.6)	9.1 (0.8)	11.4 (1.7)	16.6 (3.8)	—
Prevalence, age-adjusted, %	14.5 (1.1)	11.9 (0.8)	11.0 (0.6)	11.4 (0.6)	11.8 (1.4)	16.3 (2.8)	—
Prevalence ratios							
Model 1	1.17 (0.85 to 1.61)	1.21 (0.91 to 1.61)	1.00	1.48 (1.14 to 1.91)	1.84 (1.29 to 2.61)	2.67 (1.68 to 4.24)	<0.001
Model 2	1.46 (1.14 to 1.88)	1.25 (1.00 to 1.58)	1.00	1.14 (0.95 to 1.37)	1.11 (0.84 to 1.47)	1.44 (1.03 to 2.02)	0.022
Model 3	1.23 (0.96 to 1.59)	1.13 (0.91 to 1.41)	1.00	1.08 (0.90 to 1.29)	1.06 (0.84 to 1.34)	1.21 (0.84 to 1.72)	0.698
Model 4	0.93 (0.67 to 1.28)	1.09 (0.84 to 1.40)	1.00	1.44 (1.12 to 1.83)	1.81 (1.31 to 2.49)	1.90 (1.22 to 2.97)	<0.001
Men							
n	606	992	1043	923	123	59	
Prevalence, unadjusted, %	8.1 (1.1)	9.1 (1.3)	8.9 (1.0)	13.1 (1.3)	19.8 (3.3)	25.2 (6.1)	—
Prevalence, age-adjusted, %	17.3 (1.3)	17.1 (1.3)	16.3 (0.9)	17.3 (1.2)	17.2 (1.9)	24.0 (4.2)	—
Prevalence ratios							
Model 1	0.91 (0.64 to 1.30)	1.03 (0.71 to 1.49)	1.00	1.48 (1.08 to 2.03)	2.24 (1.56 to 3.21)	2.84 (1.72 to 4.69)	<0.001
Model 2	1.14 (0.86 to 1.52)	1.16 (0.83 to 1.63)	1.00	1.10 (0.85 to 1.44)	1.12 (0.85 to 1.48)	1.47 (0.88 to 2.46)	0.772
Model 3	1.01 (0.77 to 1.33)	1.10 (0.79 to 1.53)	1.00	1.04 (0.79 to 1.36)	1.03 (0.77 to 1.38)	1.22 (0.75 to 1.99)	0.960
Model 4	0.80 (0.57 to 1.13)	1.01 (0.72 to 1.43)	1.00	1.45 (1.06 to 1.97)	2.06 (1.46 to 2.93)	2.04 (1.17 to 3.55)	<0.001
Women							
n	624	929	1131	1011	181	68	
Prevalence, unadjusted, %	6.4 (1.2)	5.6 (0.7)	3.8 (0.4)	6.1 (0.7)	6.9 (1.9)	11.7 (4.2)	—
Prevalence, age-adjusted, %	12.4 (1.7)	7.8 (0.8)	7.0 (0.7)	7.4 (0.6)	8.2 (1.7)	10.2 (2.4)	—
Prevalence ratios							
Model 1	1.69 (1.05 to 2.72)	1.48 (1.06 to 2.07)	1.00	1.60 (1.19 to 2.15)	1.81 (0.98 to 3.35)	3.08 (1.50 to 6.33)	0.001
Model 2	2.19 (1.52 to 3.15)	1.39 (1.12 to 1.72)	1.00	1.29 (1.02 to 1.62)	1.24 (0.80 to 1.91)	1.67 (1.06 to 2.64)	<0.001
Model 3	1.70 (1.14 to 2.52)	1.21 (0.99 to 1.47)	1.00	1.22 (0.98 to 1.53)	1.13 (0.71 to 1.79)	1.21 (0.71 to 2.08)	0.110
Model 4	1.16 (0.69 to 1.97)	1.28 (0.95 to 1.73)	1.00	1.42 (1.05 to 1.92)	1.61 (0.92 to 2.81)	1.82 (0.88 to 3.76)	0.037

Model 1 is unadjusted. Model 2 is adjusted for age. Model 3 is adjusted for age; sex (except sex-specific models); race or ethnicity; educational status; leisure-time physical activity; body mass index; and histories of arthritis, cancer, chronic obstructive pulmonary disease, liver condition, thyroid problems, and sleep disorders. Model 4 is adjusted for all variables in Model 3 except age.

Results for the maximally adjusted models for men and women did not differ statistically (*P* interaction=0.100).

The unadjusted percentages of adults with a predicted 10-year cardiovascular risk <7.5% were 70.2%, 69.0%, 74.0%, 69.6%, 63.9%, and 62.0% among participants who reported sleeping ≤5, 6, 7, 8, 9, and ≥10 hours per night, respectively (Table 4). In the maximally adjusted model, sleep duration remained significantly associated with cardiovascular risk <7.5%, and participants who reported sleeping 9 hours were less likely to have a risk <7.5% than participants who slept 7 hours. The associations between sleep duration and risk <7.5% did not differ significantly between men and women ($P_{interaction}$=0.537).

Table 4. Prevalence (SE) of Predicted 10-Year Cardiovascular Risk <7.5% and Prevalence Ratios (95% CI) for Associations of Between Sleep Duration and Cardiovascular Risk Among Adults Aged 40 to 79 Years Who Were Free of Self-Reported Cardiovascular Disease, National Health and Nutrition Examination Survey 2005–2012

	Habitual Sleep Duration (Hours per Night)						$P_{\text{Wald chi-square}}$
	≤5	6	7	8	9	≥10	
Total							
n	1230	1921	2174	1934	304	127	
Prevalence, unadjusted, %	70.2 (1.9)	69.0 (1.7)	74.0 (1.2)	69.6 (1.5)	63.9 (3.8)	62.0 (6.0)	—
Prevalence, age-adjusted, %	60.8 (1.6)	61.5 (1.1)	67.3 (0.7)	66.1 (1.1)	65.2 (2.5)	61.9 (3.8)	—
Prevalence ratios							
Model 1	0.95 (0.89 to 1.01)	0.93 (0.88 to 0.99)	1.00	0.94 (0.90 to 0.99)	0.86 (0.77 to 0.97)	0.84 (0.69 to 1.02)	0.003
Model 2	0.91 (0.87 to 0.96)	0.92 (0.88 to 0.96)	1.00	0.96 (0.91 to 1.01)	0.91 (0.84 to 0.99)	0.89 (0.77 to 1.02)	0.001
Model 3	0.97 (0.92 to 1.02)	0.96 (0.92 to 1.01)	1.00	0.95 (0.91 to 1.00)	0.87 (0.81 to 0.94)	0.88 (0.76 to 1.01)	0.001
Model 4	1.03 (0.98 to 1.09)	0.97 (0.92 to 1.03)	1.00	0.94 (0.90 to 0.99)	0.83 (0.75 to 0.93)	0.89 (0.74 to 1.08)	<0.001
Men							
n	606	992	1043	923	123	59	
Prevalence, unadjusted, %	57.2 (3.1)	60.6 (2.6)	62.2 (1.9)	56.6 (2.3)	44.1 (7.2)	49.6 (8.6)	—
Prevalence, age-adjusted, %	46.4 (2.0)	51.5 (1.5)	55.0 (1.2)	51.9 (1.4)	50.8 (5.4)	51.4 (5.0)	—
Prevalence ratios							
Model 1	0.92 (0.81 to 1.04)	0.97 (0.87 to 1.09)	1.00	0.91 (0.83 to 1.00)	0.71 (0.51 to 0.98)	0.80 (0.56 to 1.13)	0.041
Model 2	0.86 (0.77 to 0.95)	0.93 (0.85 to 1.01)	1.00	0.91 (0.84 to 0.99)	0.83 (0.66 to 1.05)	0.95 (0.74 to 1.21)	0.034
Model 3	0.91 (0.82 to 1.02)	0.95 (0.88 to 1.04)	1.00	0.92 (0.86 to 0.99)	0.86 (0.69 to 1.07)	1.00 (0.79 to 1.26)	0.177
Model 4	1.02 (0.90 to 1.15)	1.00 (0.89 to 1.11)	1.00	0.92 (0.83 to 1.01)	0.72 (0.53 to 0.98)	0.91 (0.66 to 1.25)	0.049
Women							
n	624	929	1131	1011	181	68	
Prevalence, unadjusted, %	82.2 (1.6)	78.6 (1.8)	84.5 (1.1)	79.6 (1.4)	74.3 (4.2)	69.0 (7.9)	—
Prevalence, age-adjusted, %	73.2 (1.7)	72.5 (1.1)	77.9 (0.6)	76.7 (0.9)	73.6 (1.9)	69.2 (5.6)	—
Prevalence ratios							
Model 1	0.97 (0.93 to 1.02)	0.93 (0.88 to 0.98)	1.00	0.94 (0.90 to 0.98)	0.88 (0.78 to 0.99)	0.82 (0.65 to 1.03)	0.002
Model 2	0.95 (0.91 to 1.00)	0.93 (0.89 to 0.98)	1.00	0.96 (0.92 to 1.01)	0.89 (0.83 to 0.96)	0.83 (0.71 to 0.97)	<0.001
Model 3	1.00 (0.95 to 1.04)	0.95 (0.91 to 1.00)	1.00	0.97 (0.92 to 1.01)	0.89 (0.83 to 0.96)	0.86 (0.73 to 1.02)	0.001
Model 4	1.04 (0.99 to 1.09)	0.95 (0.91 to 1.00)	1.00	0.96 (0.92 to 0.99)	0.87 (0.78 to 0.98)	0.90 (0.72 to 1.13)	<0.001

Model 1 is unadjusted. Model 2 is adjusted for age. Model 3 is adjusted for age; sex; race or ethnicity; educational status; leisure-time physical activity; body mass index; and histories of arthritis, cancer, chronic obstructive pulmonary disease, liver condition, thyroid problems, and sleep disorders. Model 4 is adjusted for all variables in Model 3 except age.

Discussion

The present results are the first to describe associations between self-reported sleep duration and predicted 10-year cardiovascular risk in a nationally representative sample of adults in the United States and thus provide novel evidence of the links between sleep duration and cardiovascular health. Based on the recently introduced ACC/AHA pooled cohort

risk equations for cardiovascular disease risk assessment, self-reported sleep duration was related to predicted 10-year cardiovascular risk in a nonlinear fashion: Risk was lowest among adults who reported sleeping 7 hours per night and increased as sleep duration lessened or lengthened. These results help identify adults who are at increased risk of cardiovascular disease and who could benefit from interventions to improve their cardiovascular health.

Although previous investigations have presented data about cardiovascular risk factors and sleep duration, these studies apparently have not examined the association between sleep duration and predicted cardiovascular risk. Other studies, however, have examined associations between sleep duration and various cardiovascular risk factors included in the risk equations[2–13]; of note, sleep duration was self-reported in all of these studies. These studies divided sleep duration into 3 to 7 categories, with most studies using 5 categories. The reference category was typically 7 or 8 hours of sleep. These studies found no associations, linear associations, and nonlinear associations between sleep duration and the cardiovascular risk factors.

Of the risk factors that are part of the risk equation, concentrations of total cholesterol varied little as a function of sleep-duration categories and consequently had little effect on differences in cardiovascular risk among categories of sleep duration. The remaining factors were all significantly or nearly significantly associated with sleep duration, mostly in a nonlinear fashion, and contributed to the differences in predicted cardiovascular risk among the sleep-duration categories, suggesting that improving cardiovascular health among short and long sleepers requires a broad-based approach to risk-factor modification. Of note were the high percentages of current smokers among adults who reported sleeping ≤5 hours per night (32%) and ≥10 hours per night (38%) compared with 17% of adults who reported sleeping 7 or 8 hours per night. Cigarette smoking is a stimulant that is associated with difficulties in initiating the sleep cycle, maintaining sleep, and waking up.[17–19] Consequently, predicted cardiovascular risk could be lowered potentially among those who reported sleeping ≤5 hours and ≥10 hours per night by aggressively implementing smoking-cessation measures.

Strengths of the present study include a nationally representative sample of US adults and the use of recently released equations to estimate predicted 10-year cardiovascular risk. Several limitations merit consideration. First, the cross-sectional design of this study precludes concluding that optimizing sleep duration could result in an improvement in cardiovascular risk; however, the results of this study indicate that risk factors for cardiovascular disease in adults who are short sleepers and long sleepers warrant attention. Second, sleep duration was obtained by self-report. Unfortunately, information to validate these measures with polysomnography or actigraphy was not available. Although limited information is available about the validity and reliability of simple self-reported questions about sleep duration,[8,20–24] similar questions have been used routinely in numerous studies, especially large-scale epidemiological ones. Third, the percentage of adults who reported sleeping ≥10 hours per night was small, making the conduct of analyses of sleep duration beyond 10 hours unfeasible. Fourth, cardiovascular disease was also self-reported, and it is conceivable that participants with subclinical disease and some participants with prevalent disease were included in the analyses. Fifth, although this analysis controlled for a sizeable number of potential confounders, the possibility remains that the results are subject to residual confounding.

In conclusion, self-reported sleep duration was associated with predicted 10-year cardiovascular risk among adults aged 40 to 79 years who were free of self-reported cardiovascular disease. These results are consistent with previous studies that have shown that sleep duration predicts cardiovascular morbidity and mortality and suggest that measures to improve cardiovascular health are indicated for short and long sleepers.

Disclosures

None.

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