ORIGINAL INVESTIGATION

Sleep Duration and Body Mass Index in a Rural Population

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Background: A growing body of epidemiological evidence suggests an association between short sleep duration and obesity. Recently, potential hormonal links have been observed that may account for the relationship. The possible connection between sleep duration and body mass index (BMI) has not been explored in rural populations. Rural populations are of interest because obesity rates are high and lifestyle patterns of nutrition, physical activity, work hours, and sleep may differ from those in urban and suburban populations. We conducted this study to determine whether short sleep duration is related to BMI and obesity in a rural population in southeast Iowa.

Methods: We conducted a cross-sectional analysis of data collected in the Keokuk County Rural Health Cohort Study, 1999-2004. Study participants were from a population-based sample consisting of 990 employed adults in a rural community in southeastern Iowa. The main outcome measure was BMI. Multiple linear regression modeling was used to adjust for potential confounding variables.

Results: Self-reported sleep duration on weeknights was negatively correlated ($\beta = -0.42$; 95% confidence interval, -0.77 to -0.07) with higher BMI after adjusting for sex, age, educational achievement, physical job demand, household income, depressive symptoms, marital status, alcohol consumption, and snoring.

Conclusion: These data support an association between short sleep duration and higher BMI in this rural population, which is consistent with the relationship found in other settings.

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Obesity rates in the United States have risen dramatically during the last 15 years.[1] This is of immense public health concern because large increases in mortality and morbidity due to chronic diseases have been predicted as a consequence.[2] This epidemic cuts across geographic, socioeconomic, and racial and ethnic categories.[3] Based on 2 national data sources, the prevalence of obesity is particularly high in rural areas.[4,5]

The reasons for the obesity epidemic seem to be multifactorial, involving an interaction of genetic, environmental, and lifestyle factors.[6] Short sleep duration, one of the potential causes of obesity, is of increasing interest. A growing number of epidemiological studies have observed this association.[7-9] Physiological studies demonstrating possible hormonal mechanisms that act through decreased leptin and increased ghrelin levels support a link between short sleep duration and heavier weight. Leptin and ghrelin levels are positively associated with satiety and hunger, respectively.[10,11]

Compared with urban and suburban dwellers, rural populations are more commonly employed in agriculture and small business,[12] have higher suicide rates,[13] and may also have a higher prevalence of risky health behaviors (eg, smoking, sedentary lifestyle, and poor diet), which together constitute a unique rural culture.[14] These features of rural life may have bearing on the potential relationship between short sleep duration and obesity.

The Keokuk County Rural Health Cohort Study (KCRHS) is an ongoing, community-based, cohort study of environmental, occupational, and general health in a rural population in southeastern Iowa.[15] Using previously collected KCRHS data, we conducted a cross-sectional analysis to explore the relationship between short sleep duration and obesity in this rural study population.

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METHODS

OVERVIEW

The KCRHS is an ongoing, prospective cohort study focusing on chronic disease and in-

Table 1. Characteristics of the Study Population

Characteristic	Value
Age, mean ± SD, y	48.31 ± 12.97
Female sex, %	52.4
No college education, %	47.7
Married, %	81.6
Body mass index, mean ± SD*	29.51 ± 5.79

*Calculated as weight in kilograms divided by height in meters squared.

jury risk factors and outcomes in an agricultural county in southeastern Iowa.[15] Keokuk County is entirely rural; the population of the largest town is fewer than 2500 persons. Round 1 data (baseline) were collected from June 1994 to February 1998, and round 2 data were gathered from April 1999 to April 2004. Details of the KCRHS methods have been published.[15] The study was approved by the University of Iowa Institutional Review Board, Iowa City.

SAMPLING

The KCRHS used a stratified random sample of farm, town, and rural nonfarm households. All persons living in a randomly selected household were eligible to participate in the KCRHS. Round 2 data were collected from 1004 households.

PARTICIPANTS

While the KCRHS includes adults and children, this analysis was limited to employed (including self-employed) adults, of which 990 were identified in the round 2 data collection. Of the 1590 adults in the cohort, 563 were excluded because they were not employed, 36 were excluded because of missing information about job demands, and 1 was excluded because of lack of residential information. We focused on employed persons because the measure of physical activity in the KCRHS was physical job demand at work (measured as physical exertion). The race and ethnicity distribution of the study population was as follows: white, non-Hispanic, 954 (96.4%); Native American, 1 (0.1%); and Hispanic, 1 (0.1%). Race and ethnicity information was unavailable for 3.4% of participants.

SURVEY QUESTIONS

Responses were obtained by in-person interview using KCRHS questionnaires. These instruments consisted largely of validated questions from established national surveys[15] and included the following.

1. Sleep duration was assessed with the open-ended question, "How many hours of sleep do you get in a typical workday?"
2. Physical activity was determined by the answer to the following question: "My job/work requires lots of physical effort." Responses were rated on a 4-point scale, as follows: 1, all or almost all of the time; 2, most of the time; 3, some of the time; and 4, none or almost none of the time.
3. Depressive symptoms were assessed using the 11-item Center for Epidemiologic Studies Depression Scale.[16]
4. Alcohol consumption was assessed using the CAGE (cut down, annoyed by criticism, guilty about drinking, eye-opener drinks) questionnaire.[17] Those who reported drinking were asked, "In general, do you have less than 1 drink a day, 1 or 2 drinks a day, 3 or 4 drinks a day, or 5 or more drinks a day?"
5. Snoring was assessed with the question, "Please estimate how often you snore, according to what others sleeping in the same room have told you." Response options were as follows: never, rarely (only once or a few times ever), sometimes (a few nights per month or under special circumstances), at least once a week but pattern may be irregular, several nights per week (3-5 nights per week), every night or almost every night, or do not know.

BODY MASS INDEX

Weight and height were measured by trained research staff using a scale and a stadiometer, both of which were calibrated on a regular basis. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.[18]

STATISTICAL ANALYSIS

Because of the complex sampling design, appropriate weights were applied in the statistical analysis. Frequencies were generated for categorical variables. Descriptive statistics for continuous variables including weighted means, standard deviations, and ranges were calculated. Significant differences were determined using the F distribution, with criteria of $P<.05$ and 95% confidence intervals excluding 1.

Selected bivariate analyses were conducted to examine the separate relationships of sleep duration to depression score and alcohol consumption. These relationships were tested using Spearman correlation coefficients.

A multivariable linear regression model was constructed to examine the relationship between sleep duration and BMI. Covariates for the model included sex, age, educational achievement, physical job demand, household income, alcohol consumption, depressive symptoms, marital status, and snoring. Ordinal variables were analyzed by creating multiple dichotomous variables. Covariates were chosen based on bivariate statistical results and relationships described previously in the literature.[7-9] We explored entering sleep duration (measured as a continuous variable) as a quadratic term in the model because others studies[10] had found a U-shaped relationship between sleep duration and BMI. It was not significant ($P=.20$) when entered this way. Sleep duration was, therefore, entered into the model as a linear term. We also looked for 2-way interactions between sleep duration and sex ($P=.87$), sleep duration and job demand ($P=.87$), and sleep duration and age ($P=.11$). All 3 product terms, however, were nonsignificant and, therefore, were excluded from the final model. The analysis was performed using statistical analysis software (SAS version 9.1; SAS Institute Inc, Cary, NC) and survey data analysis (SUDAAN version 9.0; Research Triangle Institute, Research Triangle Park, NC).

RESULTS

Table 1 summarizes the study population. The mean age of the study population was 48.3 years, and a larger proportion (52.4%) were women. The mean BMI of 29.5 approached the lower end of the class I obesity range (BMI=30-34.9).[18]

Table 2 lists mean BMI by sleep duration category. Among the sleep duration categories, the largest percentage of participants (34.6%) was found in the 7 to 7.9 hours of sleep category. Body mass index was highest for those with the shortest sleep duration (<6 hours) and decreased as sleep duration increased.

Sleep duration was negatively correlated with depression score, although the association was weak ($\rho = -0.23$; $P < .001$). In contrast, sleep duration was not correlated with alcohol intake ($\rho = -0.017$; $P = .60$).

Table 3 gives the relationship of hours of sleep and other variables to BMI. In bivariate analysis, hours of sleep, age, physical job demand, alcohol consumption, depressive symptoms, and snoring were individually and significantly associated with BMI. The multivariate model (Table 3) included the following variables: hours of sleep, sex, age, educational achievement, physical job demand, household income, alcohol consumption, depressive symptoms, snoring, and marital status in relation to BMI. Of these covariates, hours of sleep, physical job demand, and alcohol consumption were independently and negatively associated with BMI, whereas snoring was independently and positively associated with BMI. For the primary independent variable hours of sleep, the regression coefficient (β) was −0.42 (95% confidence interval, −0.77 to −0.07).

To examine the nature of the relationship between sleep duration and BMI, we entered sleep duration as a categorical variable in the full multivariable model. The point estimates for BMI (not shown) were consistent with a linear relationship.

Table 2. BMI by Sleep Duration

Sleep Duration, h	Prevalence, No. (%)	BMI, Mean (SE)
<6	110 (11.3)	30.24 (0.58)
6-6.9	247 (25.4)	30.17 (0.42)
7-7.9	34 (34.6)	29.14 (0.29)
8-8.9	235 (24.1)	29.27 (0.37)
≥9	46 (4.6)	28.25 (0.65)

Abbreviation: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared).

COMMENT

In this rural, employed population, we found that persons with short sleep duration (ie, reporting <6 hours of sleep) had a mean BMI of approximately 30, in the type I obesity range.[18] Overall, sleep duration was negatively correlated with BMI after adjustment for sex, age, educational achievement, physical job demand, household income, depressive symptoms, marital status, alcohol consumption, and snoring. Snoring was included in the model as a proxy for sleep-related breathing disorder, which has been linked with obesity. Consistent with this previously reported finding, snoring was independently associated with BMI in our study (Table 3).

For sleep duration and BMI, the regression coefficient was −0.42 (95% confidence interval, −0.77 to −0.07). In terms of the variable relationship, a 1-hour decrease in sleep duration was associated with an increase in BMI of 0.42 unit. For a person 177.8 cm (70 in) tall, 0.42 BMI unit is 1.34 kg (2.9 lb). While this amount of weight may seem trivial, it should be viewed in the context of weight gain research. There is evidence from epidemiological studies and a single, well-designed clinical cohort study that young adults in the United States gain only about 0.5 kg (1.1 pounds) per year.[19,20] Therefore, as with diet and physical activity, it is conceivable that modest but sustained changes in sleep duration could have a clinically significant effect on weight.

Several other population-based, cross-sectional studies have reported an association between short sleep duration and obesity in adults.[7,10,21,22] Overall relationships between sleep duration and BMI, however, vary among these studies. For example, Gangwisch et al[7] analyzed data from NHANES I (National Health and Nutrition Examination Survey) 1982-1992, and found that BMI decreased as sleep duration increased from 2 to 4 hours to 6 hours. Body mass index stayed about the same as sleep duration increased beyond 6 hours. In contrast, Kripke et al,[22] in their population-based study, described a monotonic trend in BMI (with values of 26-26.5) over the range of sleep duration (3 to ≥10 hours) in men. In women, however, they found a U-shaped relationship between BMI and sleep duration, with both very short and very long sleep duration associated with high BMI.[22] Taheri et al[10] and Patel et al[21] also discovered a U-shaped relationship between BMI and sleep duration, with a minimum BMI of about 7 to 8 hours. The study by Patel et al included only women, whereas the study by Taheri et al included men and women. The variability among studies on the relationship of sleep duration to BMI may be due to differences in demographic data, lifestyle, comorbid conditions such as depression, or medication use patterns among the various study populations.

We limited our analysis to adults because children's normal sleep patterns and needs differ substantially from those of adults and, therefore, should be analyzed separately. In addition, the only available measure of physical activity in the data set was related to employment. Nevertheless, 3 cross-sectional studies in children found that sleep duration was negatively correlated with BMI across the range of sleep time.[23-25]

Our finding that short sleep duration was associated with increased BMI is consistent with these other studies of adult and childhood populations. However, to our knowledge, our analysis is the first to explore this relationship in a community-based, rural population. Also, because the data examined were collected as part of a more global study of health and risk factors,[15] we were able to simultaneously examine other important covariates, including alcohol use, depressive symptoms, and snoring, which few other investigations have done.[7,21] In addition, height and weight data used to calculate BMI were collected by research personnel rather than ascertained through self-report.

There are limitations to our study. The cross-sectional design precludes determination of causality. Most studies examining the relationship between sleep duration and obesity have also been cross-sectional.[26] Among reports from longitudinal data analysis, Hasler et al[27] found that short sleep time was associated with subsequent obesity in subjects younger than 35 years but that the association diminished in older participants. Gangwisch et al[7] also observed that short sleep duration was associated with subsequent weight gain, but the association was

Table 3. Relationship of Various Factors to Body Mass Index

		Bivariate Analysis		Multivariate Analysis	
Variable	No. of Subjects	Parameter Estimates (95% CI)	Overall *P* Value	Parameter Estimates (95% CI)	Overall *P* Value
Sex			.54		.16
Male	471	0.00		0.00	
Female	519	−0.21 (−0.88 to 0.46)		0.57 (−0.23 to 1.37)	
Age, y		0.03 to 0.06	.03	0.02 (−0.01 to 0.06)	.17
Duration of sleep, h		−0.52 (−0.86 to −0.18)	.003	−0.42 (−0.77 to −0.07)	.02
Educational achievement			.91		.84
No college	472	0.00		0.00	
Some college and beyond	518	−0.04 (−0.78 to 0.69)		−0.08 (−0.86 to 0.70)	
Physical job demand			.002		.01
None/almost none of the time	224	0.00		0.00	
Some of the time	361	−0.08 (−1.12 to 0.96)		−0.19 (−1.29 to 0.92)	
Most of the time	234	0.70 (−0.42 to 1.81)		0.50 (−0.73 to 1.73)	
All/almost all of the time	171	−1.41 (−2.55 to −0.27)		−1.43 (−2.74 to −0.12)	
Household income, $			.72		.80
<20 000	202	0.00		0.00	
20 000-39 999	260	0.49 (− 0.57 to 1.56)		0.42 (−0.64 to 1.48)	
40 000-59 999	252	−0.01 (−1.05 to 1.03)		0.10 (−0.96 to 1.16)	
≥60 000	171	0.37 (−0.94 to 1.68)		0.51 (−0.80 to 1.82)	
Depressive symptoms, score (range)		0.13 (0.04 to 0.22)	.007	0.08 (−0.01 to 0.18)	.09
Marital status			>.99		.44
Married	808	0.00		0.00	
Other	182	0.00 (−1.08 to 1.08)		0.51 (−0.77 to 1.79)	
Alcohol consumed, No. of drinks per day			.04		.002
0	272	0.00		0.00	
<1	616	−0.15 (−1.04 to 0.74)		0.19 (−0.78 to 1.16)	
1-2	81	−1.53 (−2.73 to −0.32)		−1.58 (−2.89 to −0.27)	
≥3	21	−1.35 (−3.43 to 0.74)		−2.18 (−4.20 to −0.17)	
Snoring, times per week			<.001		<.001
Never	113	0.00		0.00	
Rarely*	174	0.23 (−1.07 to 1.52)		0.28 (−1.11 to 1.67)	
Sometimes†	232	1.98 (0.73 to 3.22)		2.00 (0.55 to 3.44)	
1-2‡	83	2.91 (1.51 to 4.30)		3.26 (1.77 to 4.76)	
3-5	123	4.11 (2.71 to 5.52)		4.17 (2.63 to 5.70)	
Every night or almost every night	213	4.43 (3.13 to 5.73)		4.39 (2.94 to 5.83)	

Abbreviation: CI, confidence interval.
*Only once or a few times ever.
†A few nights per month or under special circumstances.
‡At least once a week but pattern may be irregular.

modest and did not reach statistical significance. Another limitation of our study is that we did not have information on leisure time physical activity and had only a limited measure of physical activity at work. Vioque et al,[28] however, found that short sleep duration and work-related physical activity, but not leisure time physical activity, were independently associated with obesity in a cross-sectional study of 1772 adults. Also, self-reported sleep duration was used in our analyses rather than measurements from instrumentation. Previous investigators, though, have found self-report through use of a sleep log to be quite consistent with actigraphic monitoring.[29] Finally, almost all (96.4%) of the study population was white. Thus, these data do not allow us to generalize the findings to other racial and ethnic groups.

Our study adds to an expanding number of studies linking short sleep duration with obesity. It is, however, one of the few investigations examining the relationship in a rural population. It is possible that aspects of the rural lifestyle or environment may account for the linear relationship between sleep duration and BMI that we observed, whereas other studies have reported U-shaped relationships.[10,21,22] The mechanism by which these variables might be connected is unknown. Some preliminary studies, though, suggest a possible hormonal link through sleep curtailment altering levels of the appetite- and energy-modulating hormones leptin and ghrelin, respectively, thereby fostering obesity.[10,11] The percentage of adults sleeping 6 hours or less per day increased markedly between 1985 and 2004, coincident with substantial increases in BMI nationally.[30] The National Heart, Lung, and Blood Institute has recently issued a request for applications exploring mechanisms linking short sleep duration and the risk for obesity or overweight.[31] Additional longitudinal studies would be useful as part of this research agenda.

In addition to obesity, short sleep duration has been associated in prospective studies with an increased risk for diabetes[32] and coronary heart disease,[33] as well as elevated total mortality,[21,22] further emphasizing the need for additional mechanistic and intervention research on sleep, chronic diseases, and associated risk factors.

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