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Abstract

Objectives: To investigate the relationship between sleep duration and obesity in older Australian adults. **Method:** Self-reported health data were collected through the 45 and Up Study. Multinomial logistic regression models were used to test the relationship between sleep duration and body mass index, controlling for a range of demographic and health-related variables. **Results:** The sample included 45,325 Australian adults aged 55 to 95 years. The regression models demonstrated that short and long sleep were associated with obesity in 55- to 64-year-olds but not in those aged 65 years and above. **Discussion:** The present results suggest that the relationships between sleep duration and obesity previously reported in young and middle-aged adults are not evident in older adults. The absence of these relationships could reflect a combination of age-related factors that impact on sleep and body composition.

Keywords

obesity, sleep, body mass index, aging

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Introduction

Obesity is a major health and social problem worldwide that is prevalent in 25% to 30% of adults living in countries such as the United States and Australia (Cameron et al., 2003; Ogden et al., 2006). It is well documented that obesity greatly increases the risk of chronic health conditions such as diabetes, cardiovascular disease, and some cancers (Kopelman, 2000) and is also associated with poor psychosocial outcomes such as depression, poor body image, low self-esteem, and discrimination (O'Brien et al., 2008; Onyike, Crum, Lee, Lyketsos, & Eaton, 2003; Schwartz & Brownell, 2004). It is therefore important that effective interventions are developed to reduce the burden of obesity.

Short sleep (i.e., <7-hr sleep a night) is an increasingly common characteristic of modern society and is reported by 18% to 30% of adults in countries such as the United States and Australia (Kripke, Garfinkel, Wingard, Klauber, & Marler, 2002; Kripke, Simons, Garfinkel, & Hammond, 1979; Krueger & Friedman, 2009; Magee, Iverson, & Caputi, 2009). Short sleep adversely affects mood, attention, and cognitive performance (Dinges, Rogers, & Baynard, 2005), but emerging data also suggest that it is a novel risk factor for conditions such as obesity. For example, a number of recent cross-sectional studies have found that short sleep is associated with an elevated risk of obesity in young and middle-aged adults (see reviews by Cappuccio et al., 2008; Magee, Iverson, Huang, & Caputi, 2008; Nielsen, Danielsen, & Sørensen, in press; Patel & Hu, 2008; Taheri & Thomas, 2008). Prospective cohort studies have also demonstrated that short sleep at baseline predicts weight gain and obesity several years later at follow-up (Chaput, Després, Bouchard, & Tremblay, 2008; Gangwisch, Malaspina, Boden-Albala, & Heymsfield, 2005; López-García et al., 2008; Patel, Malhotra, White, Gottlieb, & Hu, 2006). Some experimental studies have also found that sleep restriction affects hormone levels and behaviors in a manner that is predictive of obesity (Magee, Huang, Iverson, & Caputi, 2010; Nedeltcheva et al., 2009; Spiegel, Tasali, Leproult, & Van Cauter, 2009).

It has therefore been argued that short sleep contributes to obesity and hence could potentially be targeted to facilitate the treatment and prevention of obesity (Flier & Elmquist, 2004; Taheri & Thomas, 2008). There is, however, a need for more research to clarify the nature and extent of the relationship between sleep and obesity. One issue that needs to be addressed is that most existing studies have examined the link between sleep and obesity in young and middle-aged adults (Cappuccio et al., 2008). Unfortunately, very few studies have been conducted on samples of older adults; these have

generally produced mixed results. For example, three studies using self-report measures of sleep found no evidence of an association between sleep duration and obesity in elderly adults (Gangwisch et al., 2005; Gottlieb et al., 2006; Yaggi, Araujo, & McKinlay, 2006). Two studies using more objective measures of sleep (i.e., actigraphy) found that short sleep was linked with an elevated risk of obesity (Patel et al., 2008; van den Berg, Knvistingh Neven, et al., 2008). These divergent findings could reflect differences in the measures used to assess sleep and/or variations in the number and type of potential confounding variables that were controlled. Other factors such as differences in the size and characteristics of these samples (e.g., different age ranges) could also account for these varying results.

Importantly, although these studies have examined the relationship between sleep duration and obesity in older adults, they have not examined how the association between sleep duration and obesity changes with advancing age. This requires investigation because considerable changes in sleep, body composition, and physical and mental health that occur with advancing age could impact on the association between sleep duration and obesity in older adults (Bliwise, 2005; Prentice & Jebb, 2001; Someren, 2000). Therefore, the purpose of the present article was to extend on previous findings and examine whether the association between sleep duration and obesity varied with increasing age in a sample of middle-aged and older adults.

Method

Sample

This article used data collected through the 45 and Up Study, which is a health survey of adults aged 45 year and above residing in the state of New South Wales (NSW), Australia. Participants were randomly selected from the Medicare Australia enrolment register and were mailed a questionnaire. The response rate for the questionnaire was approximately 18%, which indicates that the sample may not be directly representative of the general population (Banks et al., 2008). However, the 45 and Up Study was not developed to provide a representative sample, instead it aimed to collect important health information on a large, heterogeneous sample of adults and allow for meaningful comparisons of outcomes between groups within the cohort (Banks, Jorm, Lujic, & Rogers, 2009). A small proportion (<1%) of individuals independently volunteered for this study and were included in the present article. The specific methods of the 45 and Up Study are reported elsewhere in more detail (Banks et al., 2008). Informed consent was obtained

from all participants, and ethics approval for the 45 and Up Study was provided by the University of NSW Human Research Ethics Committee. Approval to use the data for this article was obtained from the University of Wollongong Human Research Ethics Committee.

The present article used baseline data from the 45 and Up Study, which was collected between 2006 and 2008. We only included data from participants aged 55 to 95 years so that we could examine how the association between sleep duration and obesity varied in middle-aged and older adults.

Materials

All variables were derived from a self-report questionnaire, except for geographic location of residence (coded as regional/remote and major city), which was determined using the standard index of geographic remoteness in Australia (Australian Bureau of Statistics, 2008). Sleep duration was assessed by the question "About how many hours in each 24-hr day do you usually spend sleeping (including at night and naps)?" The responses were coded into the following sleep categories: <6-hr sleep, 6-hr sleep (≥ 6 hr, <7 hr), 7-hr sleep (≥ 7 hr, <8 hr), 8-hr sleep (≥ 8 hr, <9 hr), and ≥ 9 -hr sleep. Consistent with previous studies examining sleep duration and health conditions in older adult samples, 7-hr sleep was used as the reference condition (Gangwisch et al., 2008; Suzuki et al., 2009). Body mass index (BMI) was determined from self-reported height and weight, and was used to classify individuals as lean (BMI = 18.5-24.9), overweight (BMI = 25.0-29.9), or obese (BMI ≥ 30) according to recommended cutoff levels (World Health Organization, 2000).

Other variables included as covariates in the present article were age, gender, alcohol consumption, smoking status, country of birth, marital status, moderate physical activity, and education level. Participants were also asked to indicate if they had ever been diagnosed with stroke, heart disease, diabetes, or any type of cancer. Levels of psychological distress were assessed using the Kessler 10 Psychological Distress Scale. This is a 10-item scale that is scored from 10 to 50 (higher scores indicate greater psychological distress), which has been shown to produce valid and reliable scores in Australian adults (Andrews & Slade, 2001).

Statistical Analysis

The data were analyzed using SPSS version 15.0, and the sample was divided into four age groups (55-64 years, 65-74 years, 75-84 years, and 85-95 years). The univariate associations between BMI categories and the covariates

(including sleep duration) were examined using chi-square and ANOVA. We also performed univariate analyses to examine how sleep duration, BMI, and other covariates differed between the age groups.

Multinomial logistic regression was used to examine the association between sleep duration and BMI categories (“lean,” “overweight,” and “obese”); two separate models were tested. The first model examined the association between sleep duration and BMI without controlling for any covariates (the unadjusted model). In the second model, the association between sleep duration and BMI was examined while controlling for the following covariates: age, gender, alcohol consumption, smoking status, country of birth, marital status, moderate physical activity, education level, history of chronic disease, and psychological distress. These models were tested for the entire sample and then separately for each of the four age categories. The results from the regression models are reported as odds ratios (OR) with 95% confidence intervals and p values. Because each model involved conducting two comparisons (i.e., lean vs. overweight and lean vs. obese), the OR were tested against a p value of .025 (two-tailed). This was to reduce the risk of a Type I error associated with performing multiple tests. Overall model fit was determined using likelihood ratio tests, and Nagelkerke R^2 was used to estimate the proportion of the variance in BMI accounted for by the covariates.

Results

Descriptive Data

The sample included 45,325 Australian adults aged 55 to 95 years, of whom 52.9% were male. A total of 21.0% of individuals were obese, 2.6% reported <6-hr sleep, 12.0% reported 6-hr sleep, and 19.5% reported ≥ 9 -hr sleep. The demographic characteristics of the sample are shown in Table 1 and are broken down according to BMI categories. The univariate analyses indicate that factors such as short and long sleep, lower education level, former smoking, and lower physical activity levels were significantly associated with obesity in the entire sample. Furthermore, obese individuals were significantly more likely to report higher levels of psychological distress and indicate that they had been previously diagnosed with diabetes, stroke, or heart disease.

We also examined the demographic characteristics for the sample broken down by age group (see Table 2). This demonstrates that the proportion of individuals who were obese declined with age from 24.2% in 55- to 64-year-olds to only 8.3% in the 85 to 95 age group. The proportion of individuals

Table 1. Demographic Characteristics of the Sample According to BMI Category (N = 45,325)

Variable	Lean (n = 16,658; 36.8%)		Overweight (n = 19,145; 42.2%)		Obese (n = 9,522; 21.0%)		Total (n = 45,325)		p value ^a
	n	%	n	%	n	%	n	%	
Gender									<.001
Male	7,632	45.8	11,588	60.5	4,781	50.2	24,001	53.0	
Female	9,026	54.2	7,557	39.5	4,741	49.8	21,324	47.0	
Sleep duration									<.001
<6 hr	420	2.5	454	2.4	316	3.3	1,190	2.6	
6 hr	1,910	11.5	2,228	11.6	1,304	13.7	5,442	12.0	
7 hr	4,074	24.5	4,751	24.8	2,092	22.0	10,917	24.1	
8 hr	7,105	42.7	8,013	41.9	3,841	40.3	18,959	41.8	
≥9 hr	3,149	18.9	3,699	19.3	1,969	20.7	8,817	19.5	
Age category									<.001
55-64 years	8,042	48.3	9,736	50.9	5,680	59.7	23,458	51.8	
65-74 years	4,802	28.8	6,212	32.4	2,834	29.8	13,848	30.6	
75-84 years	3,143	18.9	2,826	14.8	914	9.6	6,883	15.2	
85-95 years	671	4.0	371	1.9	94	1.0	1,136	2.5	
Marital status									<.001
Single	4,015	24.1	3,863	20.2	2,136	22.4	10,014	22.1	
Married/ de facto	12,643	75.9	15,282	79.8	7,386	77.6	35,311	77.9	
Education level									<.001
<high school	1,478	8.9	2,026	10.6	1,307	13.7	4,811	10.6	
High school	5,426	32.6	6,116	31.9	3,395	35.7	14,937	33.0	
Trade/diploma	5,378	32.3	6,633	34.6	3,108	32.6	15,119	33.4	
University	4,376	26.3	4,370	22.8	1,712	18.0	10,458	23.1	
Country of birth									<.001
Australia	11,928	71.6	14,248	74.4	7,375	77.5	33,551	74.0	
Other	4,730	28.4	4,897	25.6	2,147	22.5	11,774	26.0	
Area of residence									<.001
Remote/ regional	8,948	53.7	11,071	57.8	5,768	60.6	25,787	56.8	
Major city	7,710	46.3	8,074	42.2	3,754	39.4	19,538	43.1	
Smoking status									<.001
Never	9,886	59.3	10,346	54.0	4,861	51.1	25,093	55.4	
Former	5,720	34.3	7,882	41.2	4,193	44.0	17,795	39.3	
Current	1,052	6.3	917	4.8	468	4.9	2,437	5.4	

(continued)

Table I. (continued)

Variable	Lean (n = 16,658; 36.8%)		Overweight (n = 19,145; 42.2%)		Obese (n = 9,522; 21.0%)		Total (n = 45,325)		p value ^a
	n	%	n	%	n	%	n	%	
Alcohol (drinks/ week)									<.001
0	4,967	29.8	5,286	27.6	3,502	36.8	13,755	30.3	
1-7	6,173	37.1	6,493	33.9	3,102	37.1	15,768	34.8	
8-14	3,284	19.7	3,813	19.9	1,364	14.3	8,461	18.7	
>14	2,234	13.4	3,553	18.6	1,554	16.3	7,341	16.2	
Physical activity									<.001
<30 min/day	8,642	51.9	10,519	54.9	5,627	59.1	24,788	54.7	
≥30 min/day	8,016	48.1	8,626	45.1	3,895	40.9	20,537	45.3	
Psychological distress (K10) ^b									<.001
K10, M (SD)	13.1 (4.2)		13.2 (4.3)		14.1 (5.2)		13.3 (4.5)		
History of									
Diabetes	904	5.4	1,667	8.7	1,687	17.7	4,258	9.4	<.001
Stroke	562	3.4	629	3.3	362	3.8	1,553	3.4	<.001
Heart disease	2,209	13.3	2,864	15.0	1,456	15.3	6,529	14.4	<.001
Cancer	2,328	14.0	2,634	13.8	1,265	13.3	6,227	13.7	.294

Note: BMI = body mass index.

a. p value refers to a chi-square test results examining univariate associations between each variable and BMI category (unless specified otherwise).

b. Data are presented as means and standard deviations; p value refers to the results of ANOVA.

who were overweight was also significantly lower in the 85 to 95 age group compared to the other groups. The percentage of individuals reporting <6-hr sleep and 6-hr sleep was fairly consistent across the age groups, whereas long sleep (i.e., ≥9-hr sleep) was more common in the older groups. Individuals in the older groups were also less likely to have been born in Australia, currently smoke, drink excessively, and exercise for 30 min or more a day, and were more likely to report chronic health conditions such as heart disease.

Multivariate Multinomial Logistic Regression

The unadjusted and adjusted OR (AOR) for the models predicting the BMI categories (i.e., lean, overweight, and obese) for the entire sample are

Table 2. Demographic Characteristics of the Sample According to Age Category (N = 45,325)

	55-64 years (n = 23,458; 51.8%)		65-74 years (n = 13,848; 30.6%)		75-84 years (n = 6,883; 15.2%)		85-95 years (n = 1,136; 2.5%)		p value ^a
	n	%	n	%	n	%	n	%	
Gender									<.001
Male	11,108	47.4	7,787	56.2	4,428	64.3	678	59.7	
Female	12,350	52.6	6,061	43.8	2,455	35.7	458	40.3	
Sleep duration									<.001
<6 hr	607	2.6	336	2.4	202	2.9	45	4.0	
6 hr	2,977	12.7	1,557	11.2	773	11.2	135	11.9	
7 hr	6,389	27.2	3,092	22.3	1,257	18.3	179	15.7	
8 hr	9,972	42.5	5,797	41.8	2,775	40.3	415	36.5	
≥9 hr	3,513	15.0	3,066	22.1	1,876	27.3	362	31.9	
Body weight status									<.001
Lean	8,042	34.3	4,802	34.7	3,143	45.7	671	59.0	
Overweight	9,736	41.5	6,212	44.9	2,826	41.1	371	32.7	
Obese	5,680	24.2	2,834	20.5	914	13.3	94	8.3	
Marital status									<.001
Single	4,616	19.7	2,804	20.2	2,015	29.3	579	51.0	
Married/ de facto	1,8842	80.3	11,044	79.8	4,868	70.7	557	49.0	
Education level									<.001
<High school	1,862	7.9	1,760	12.7	984	14.3	205	18.0	
High school	7,598	32.4	4,630	33.4	2,314	33.6	395	34.8	
Trade/diploma	7,677	32.7	4,798	34.6	2,301	33.4	343	30.2	
University	6,321	26.9	2,660	19.2	1,284	18.7	193	17.0	
Country of birth									<.001
Australia	17,586	75.0	10,252	74.0	4,982	72.4	731	64.3	
Other	5,872	25.0	3,596	26.0	1,901	27.6	405	35.7	
Area of residence									<.001
Remote/ regional	13,759	58.6	8,426	60.8	3,203	46.5	399	35.1	
Major city	9,699	41.3	5,422	39.2	3,680	53.5	737	64.9	
Smoking status									<.001
Never	13,186	56.2	7,521	54.3	3,707	53.9	679	59.7	
Former	8,574	36.6	5,736	41.4	3,041	44.2	444	39.1	
Current	1,698	7.2	591	4.3	135	2.0	13	1.1	

(continued)

Table 2. (continued)

	55-64 years (n = 23,458; 51.8%)		65-74 years (n = 13,848; 30.6%)		75-84 years (n = 6,883; 15.2%)		85-95 years (n = 1,136; 2.5%)		p value ^a
	n	%	n	%	n	%	n	%	
Alcohol (drinks/ week)									<.001
0	6,481	27.6	4,342	31.4	2,450	35.6	482	42.4	
1-7	8,439	36.0	4,586	33.1	2,348	34.1	395	34.8	
8-14	4,487	19.1	2,576	18.6	1,227	17.8	171	15.1	
>14	4,051	17.3	2,344	16.9	858	12.5	88	7.7	
Physical activity									
<30 min/day	13,441	57.3	6,984	50.4	3,661	53.2	702	61.8	
≥30 min/day	10,017	42.7	6,864	49.6	3,222	46.8	434	38.2	<.001
Psychological distress ^b (K10)									
M (SD)	13.7	4.8	12.9	4.1	12.9	4.0	13.5	4.1	<.001
History of									
Diabetes	1,728	7.4	1,573	11.4	852	12.4	105	9.2	<.001
Stroke	384	1.6	558	4.0	496	7.2	115	10.1	<.001
Cardiovascular disease	1,987	8.5	2,325	16.8	1,894	27.5	323	28.4	<.001
Cancer	3,407	14.5	1,720	12.4	935	13.6	165	14.5	<.001

a. p value refers to a chi-square test results examining univariate associations between each variable and BMI category (unless specified otherwise).

b. Data are presented as means and standard deviations; p value refers to the results of ANOVA.

shown in Table 3; for reasons of clarity, we focus primarily on the adjusted analyses in the remainder of this article. The adjusted model for the entire sample had a good model fit, $\chi^2_{46} = 4176.86, p < .001$, with the combination of covariates accounting for 10% of the variance in BMI ($R^2 = .10$). The results indicated that <6-hr sleep (AOR = 1.30, 95% confidence interval [CI] = 1.10-1.53, $p = .002$), 6-hr sleep (AOR = 1.26, 95% CI = 1.15-1.38, $p < .001$), and ≥9-hr sleep (AOR = 1.17, 95% CI = 1.07-1.26, $p < .001$) were significantly associated with elevated odds of obesity. These findings suggest a U-shaped association between sleep duration and obesity in the present sample of adults aged 55 to 95 years. Neither short nor long sleep was significantly associated with an increased likelihood of being overweight.

Table 3. Relationship Between Sleep Duration and Obesity for the Entire Sample ($n = 45,325$)—Results From the Adjusted and Unadjusted Models

	Overweight		Obese		<i>p</i> value
Model 1					
Sleep category					<.001
<6 hr	0.93	0.81-1.07	1.47*	1.26-1.71	
6 hr	1.00	0.93-1.08	1.33*	1.22-1.45	
7 hr	ref		ref		
8 hr	0.97	0.92-1.02	1.05	0.99-1.12	
≥9 hr	1.01	0.95-1.07	1.22*	1.13-1.32	
Model 2					
Sleep category					<.001
<6 hr	0.97	0.84-1.12	1.30*	1.10-1.53	
6 hr	1.02	0.94-0.95	1.26*	1.15-1.38	
7 hr	ref		ref		
8 hr	0.95	0.90-1.01	1.05	0.98-1.12	
≥9 hr	0.96	0.90-1.02	1.17*	1.07-1.26	
Age	0.98*	0.97-0.98	0.95*	0.94-0.95	<.001
Sex					<.001
Male	1.84*	1.76-1.93	1.30*	1.23-1.38	
Female	ref		ref		
Marital status					.011
Single	0.93*	0.88-0.98	1.00	0.94-1.07	
Married/ de facto	ref		ref		
Education level					<.001
<High school	1.59*	1.47-1.73	2.31*	2.09-2.55	
High school	1.30*	1.23-1.38	1.67*	1.55-1.80	
Trade/ diploma	1.24*	1.17-1.31	1.47*	1.36-1.58	
University	ref		ref		
Country of birth					<.001
Australia	0.87*	0.82-0.91	0.74*	0.69-0.78	
Other	ref		ref		
Area of residence					<.001
Remote/ regional	1.13*	1.08-1.18	1.17*	0.94-1.07	
Major city	ref		ref		

(continued)

Table 3. (continued)

	Overweight		Obese		p value
Smoking status					<.001
Never	ref		ref		
Former	1.15*	1.10-1.21	1.46*	1.38-1.55	
Current	0.67*	0.60-0.73	0.61*	0.54-0.69	
Alcohol (drinks/week)					<.001
0	1.08*	1.02-1.14	1.36*	1.28-1.45	
1-7	ref		ref		
8-14	1.03	0.97-1.09	0.79*	0.73-0.86	
>14	1.20*	1.13-1.29	1.14*	1.05-1.24	
Physical activity					<.001
<30 min/day	1.11*	1.07-1.16	1.28*	1.22-1.35	
≥30 min/day	ref		ref		
Depression (K10)	1.01	1.00-1.01	1.03*	1.02-1.03	<.001
History of					<.001
Diabetes	1.59*	1.46-1.74	3.59*	3.28-3.92	
Stroke	0.95	0.85-1.08	1.04	0.90-1.21	.434
Heart disease	1.09*	1.03-1.17	1.18*	1.10-1.28	<.001
Cancer	0.98	0.92-1.04	0.92	0.85-0.99	.107

Note: Ref = referent.

**p* < .025.

When the analyses were stratified by age, the pattern of the relationship varied with increasing age (see Figure 1A-1D and Table 4). The results also indicated that none of the sleep categories were associated with overweight in any of the age groups; thus, we only present the obese versus lean comparison in Table 4. For the 55 to 64 years age group, the model had a good fit, $\chi^2_{44} = 2335.57$, *p* < .001, and accounted for 11% of the variance in BMI (Nagelkerke *R*² = .11). The results demonstrated that <6-hr sleep (AOR = 1.52, 95% CI = 1.21-1.89, *p* < .001), 6-hr sleep (AOR = 1.42, 95% CI = 1.26-1.61, *p* < .001), and ≥9-hr sleep (AOR = 1.19, 95% CI = 1.06-1.34, *p* < .001) were associated with obesity.

In the unadjusted analysis for the 65 to 74 age group, 6-hr sleep (OR = 1.24, 95% CI = 1.05-1.47, *p* < .001) and ≥9-hr sleep (OR = 1.35, 95% CI = 1.17-1.55, *p* < .001) were associated with obesity. However, these effects attenuated and were not significant in the adjusted analyses perhaps because

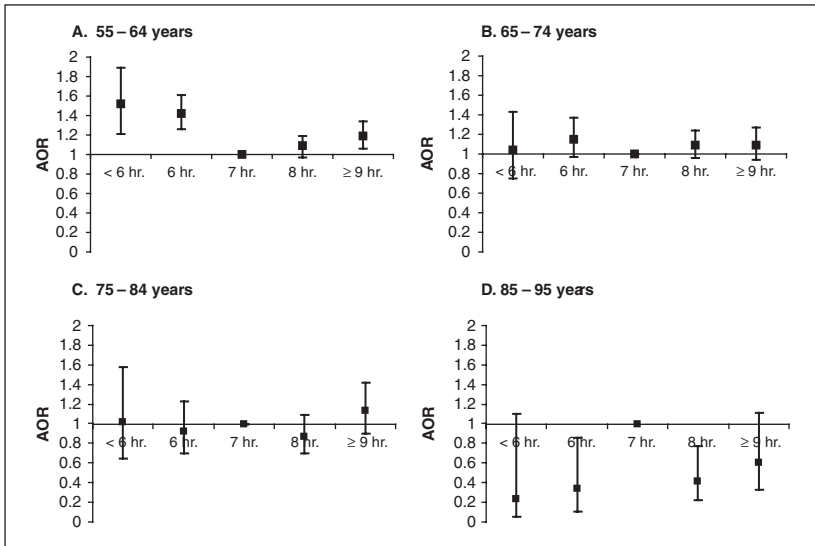


Figure 1. Adjusted odds ratios for the association between sleep duration and obesity for each age group

Note: AOR = adjusted odds ratios.

of factors such as diabetes (AOR = 3.41, 95% CI = 2.93-3.96, $p < .001$), heart disease (AOR = 1.16, 95% CI = 1.02-1.33, $p < .001$), and physical activity levels (AOR = 1.44, 95% CI = 1.31-1.58, $p < .001$). The model fit for this age group was good, $\chi^2_{44} = 1001.25$, $p < .001$, and the variables accounted for 8% of the variance in BMI ($R^2 = .08$).

The adjusted models for the 75 to 84 age group, $\chi^2_{44} = 327.89$, $p < .001$; $R^2 = .05$, and the 85 to 95 age group, $\chi^2_{42} = 79.68$, $p < .001$; $R^2 = .08$, fit the data well, but there was no evidence that short or long sleep were significantly associated with increased odds of overweight or obesity.

Discussion

The purpose of this study was to clarify the association between sleep duration and obesity in a large cross-sectional study of older adults. This study is important because there have been a number of studies examining the relationship between sleep duration and obesity in young and middle-aged adults, but very few studies have been conducted in older adults. Furthermore, the

Table 4. Results for the Multinomial Logistic Regression Broken Down by Age Group

	55-64 years			65-74 years			75-84 years			85-95 years		
	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Model 1												
Sleep category												
<6 hr	1.94*	1.57-2.39		1.26	0.93-1.72		1.23	0.80-1.89		0.31	0.07-1.39	
6 hr	1.58*	1.41-1.77		1.24*	1.05-1.47		1.06	0.80-1.40		0.39	0.16-0.91	
7 hr	ref			ref			ref			ref		
8 hr	1.13*	1.04-1.23	<.001	1.14	1.01-1.29	<.001	0.89	0.72-1.11	<.001	0.42*	0.23-0.78	<.001
≥9 hr	1.47*	1.32-1.64		1.35*	1.17-1.55		1.23	0.98-1.53		0.71	0.39-1.27	
Model 2												
Sleep category												
<6 hr	1.52*	1.21-1.89	<.001	1.04	0.75-1.43	.454	1.02	0.65-1.58	.170	0.23	0.05-1.11	.093
6 hr	1.42*	1.26-1.61		1.15	0.97-1.37		0.92	0.70-1.23		0.34	0.14-0.83	
7 hr	ref			ref			ref			ref		
8 hr	1.06	0.97-1.16		1.09	0.96-1.24		0.87	0.70-1.09		0.41	0.22-0.77	
≥9 hr	1.19*	1.06-1.34		1.09	0.94-1.27		1.13	0.90-1.42		0.59	0.32-1.10	
Sex												
Male	1.55*	1.43-1.68	<.001	1.14*	1.02-1.27	<.001	0.81*	0.68-0.97	<.001	0.61	0.35-1.05	.001
Female	ref			ref			ref			ref		
Marital status												
Single	0.95	0.87-1.04	.159	1.02	0.90-1.14	<.001	1.05	0.88-1.24	.855	0.79	0.49-1.29	.064
Married/de facto	ref			ref			ref			ref		
Education level												
<High school	2.27*	1.96-2.63	<.001	2.04*	1.71-2.43	<.001	2.40*	1.80-3.18	<.001	2.12	0.94-4.79	.504
High school	1.67*	1.51-1.83		1.41*	1.22-1.63		1.99*	1.56-2.55		1.30	0.61-2.78	
Trade/diploma	1.50*	1.36-1.65		1.22*	1.06-1.41		1.75*	1.37-2.24		1.73	0.81-3.69	
University degree	ref			ref			ref			ref		

(continued)

Table 4. (continued)

	55-64 years			65-74 years			75-84 years			85-95 years		
	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p	OR	95% CI	p
Country of birth												
Australia	0.64*	0.59-0.70	<.001	0.74	0.66-0.82	<.001	1.08	0.91-1.29	.525	1.14	0.71-1.82	.741
Other	ref			ref			ref			ref		
Area of residence												
Remote/regional	1.19*	1.10-1.28	<.001	1.15*	1.04-1.27	.021	1.08	0.93-1.26	.217	0.92	0.56-1.51	.138
Major city	ref			ref			ref			ref		
Smoking status												
Never	ref		<.001	ref		<.001	ref		<.001	ref		.229
Former ^a	1.48*	1.37-1.60		1.54*	1.39-1.71		1.21	1.02-1.42		1.55	0.94-2.57	
Current ^a	0.63*	0.54-0.72		0.66*	0.51-0.85		0.55	0.31-1.00				
Alcohol (drinks/week)												
0	1.53*	1.40-1.67	<.001	1.18*	1.05-1.33	<.001	1.18	0.98-1.41	.014	1.11	0.65-1.89	.755
1-7	ref			ref			ref			ref		
8-14	0.75	0.68-0.83		0.80*	0.69-0.93		1.05	0.83-1.32		0.76	0.65-1.65	
>14	1.07	0.96-1.20		1.14	0.98-1.33		1.39*	1.07-1.81		1.72	0.71-4.19	
Physical activity												
<30 min/day	1.22*	1.13-1.31	<.001	1.44*	1.31-1.58	<.001	1.36*	1.17-1.59	<.001	2.70*	1.54-4.72	.001
≥30 min/day	ref			ref			ref			ref		
Depression (K10)	1.03*	1.02-1.04	<.001	1.03*	1.02-1.04	<.001	1.03*	1.01-1.05	.006	1.05	1.00-1.10	.033
History of												
Diabetes	4.26*	3.68-4.94	<.001	3.41*	2.93-3.96	<.001	2.67*	2.17-3.27	<.001	1.59	0.81-3.13	.429
Stroke	1.24	0.93-1.64	.321	1.12	0.88-1.42	.647	0.97	0.73-1.28	.096	0.69	0.30-1.58	.449
Heart disease	1.26*	1.11-1.44	.001	1.16*	1.02-1.33	.054	1.11	0.94-1.32	.430	1.00	0.61-1.65	.996
Cancer	0.95	0.86-1.05	.372	0.90	0.78-1.05	.342	0.85	0.67-1.07	.111	1.01	0.53-1.93	.526

Note: OR = odds ratio; CI = confidence interval. Ref = referent. Odds ratios and 95% CI are presented for the obese versus lean comparison. The overweight versus lean comparison is not presented; none of the sleep categories were significantly associated with overweight in any of the age groups.

a. Former and current smoking categories were combined for the 85 to 95 age group because of low cell numbers.

*p < .025.

available data have produced mixed results. For example, three studies reported no evidence of an association between sleep duration and obesity in samples of adults aged between 40 and 93 years (Gangwisch et al., 2005; Gottlieb et al., 2006; Yaggi et al., 2006). In contrast, van den Berg, Knvistingh Neven, et al. (2008) and Patel et al. (2008) both assessed sleep using actigraphy in 983 adults aged 57 to 97 years and 6,107 adults aged 67 to 99 years, respectively, and found evidence for an association between short sleep and obesity.

In the present study, we found that short sleep duration was associated with an increased risk of obesity in the entire sample of adults aged 55 to 95 years, which supports the findings of van den Berg, Knvistingh Neven, et al. (2008) and Patel et al. (2008). In addition, the present study also found that long sleep was associated with increased obesity risk, which supports Patel et al. and is consistent with some studies in young and middle-aged adults (Cappuccio et al., 2008).

The key strength of the present study was the large sample size, which allowed us to break the sample down into smaller age groups. Hence, we were able to examine whether the association between sleep duration and obesity varied with increasing age. Our results demonstrate that short and long sleep were associated with obesity in adults aged 55 to 64 year olds but not in adults aged 65 years and above. To our knowledge, this pattern of results has not been previously reported and indicates that short and long sleep are independently associated with obesity in middle-aged adults but that these associations diminish with advancing age.

Because the present study used cross-sectional data, we are unable to determine the temporal association between short sleep and obesity in the 55 to 64 age group. This is an important consideration because available data indicate that the relationship between short sleep and obesity is likely to be bidirectional. For example, prospective data indicate that short sleep at baseline predicts weight gain and obesity risk in young adults (results are mixed in older adults), and there are a number of plausible explanations for this. First, laboratory-based studies indicate that sleep restriction alters levels of hormones, such as leptin, ghrelin, and peptide-YY, and glucose regulation in a manner that could promote obesity over time (Knutson, Spiegel, Penev, & Van Cauter, 2007; Magee et al., 2010; Spiegel et al., 2009). It is also possible that short sleepers have more opportunities (i.e., time) to eat, and this could also explain why they are more likely to be obese (Nedeltcheva et al., 2009). Conversely, weight gain and obesity are associated with obstructive sleep apnea, which is a condition characterized by partial or complete obstructions of the upper airway during sleep caused by excessive body fat. Obstructive sleep

apnea is associated with poor sleep quality and short sleep in obese individuals (Vgontzas et al., 1994). Other factors associated with obesity such as pain and general discomfort may also increase the risk of short sleep (Magee et al., 2010). Thus, the relationship between short sleep and obesity is likely to be bidirectional and cyclical (e.g., short sleep contributes to weight gain and weight gain causes short sleep) and hence needs to be examined through more prospective studies (Magee et al., 2010; Nielsen, Danielsen, & Sørensen, in press).

The association between long sleep and obesity observed in middle-aged adults in the present study is also interesting and has been reported by some previous studies (López-García et al., 2008; van den Berg, Knvistingh Neven, et al., 2008). The precise mechanisms linking long sleep to obesity are not well elucidated but are likely to differ from those underpinning the association between short sleep and obesity. For example, it is generally agreed that long sleep does not contribute to obesity; instead, it is a marker of underlying health conditions that are associated with obesity (Patel, Malhotra, Gottlieb, White, & Hu, 2006).

There are a number of feasible explanations for the lack of an association between short sleep and obesity in older adults. First, inaccuracies associated with the use of self-report measures of sleep, body height, and body weight are generally more pronounced in older populations. For example, the accuracy of self-reported sleep appears to decline with age and is affected by factors such as sleep quality and health status (Lauderdale et al., 2006; Lauderdale, Knutson, Yan, Liu, & Rathouz, 2008; Lockley, Skene, & Arendt, 1999; van den Berg, Van Rooij, et al., 2008). This may partially explain the lack of a significant association between sleep duration and obesity in older adults. However, most elderly adults (64%) are able to estimate their sleep duration to within one hour of sleep measured using actigraphs (van den Berg, Van Rooij, et al., 2008). Therefore, although the present study relied on self-report measures, the combination of the very large sample size and inclusion of a vast array of covariates provide important insights into the relationship between sleep and obesity in older adults.

Instead, we argue that the absence of an association between sleep duration and obesity in older adults is more likely the result of a number of age-related factors. For example, there are substantial lifestyle (e.g. retirement, loss of a spouse) and physiological changes that occur with advancing age that affect sleep patterns and body composition (Bliwise, 2005; Prentice & Jebb, 2001). For example, mental health disorders (e.g., depression), chronic medical conditions (e.g., diabetes, cancer, cardiovascular disease), sleep disorders (e.g., insomnia), and increased use of medication become more common in the elderly, and these factors influence sleep patterns and body

composition (Jensen & Rogers, 1998; Someren, 2000). Furthermore, obesity and short sleep are independently associated with increased mortality risk (Gangwisch et al., 2008; Kopelman, 2000), and, consequently, it is possible that individuals who are obese and/or report short or long sleep do not live as long as their peers. A combination of these factors could explain why there was not an association between sleep duration and obesity in the older adult groups.

As noted, the main strength of the present article was the large sample size, which enabled us to examine whether the association between sleep duration and obesity varies with age. We were also able to control for a vast array of covariates that could potentially confound the association between sleep and obesity. However, the use of self-report measures of sleep duration and the use of cross-sectional data are potential limitations. Addressing these factors in large-scale prospective studies in older adult populations will be important in clarifying how the nature of the association between sleep duration and obesity varies with age.

The present study demonstrates that short and long sleep duration were associated with obesity in adults aged 55 to 64 years, but these associations diminished and were not evident in older adults. This finding suggests that short sleep could be a risk factor for obesity in young and middle-aged adults, whereas long sleep is likely to be a marker of obesity-related comorbidities. However, elevated mortality associated with short sleep and obesity along with considerable changes in health status is likely to account for the lack of association between sleep duration and obesity in the elderly. These results are important because short sleep could be an important predictor of obesity and associated chronic diseases in middle-aged adults. Hence, short sleep could be targeted through behavioral interventions or treatment from specialist practitioners as a way to reduce morbidity and mortality and promote healthy aging.

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