Original Research Article

Sleep Duration, Sleep Quality, and Obesity Risk Among Older Adults From Six Middle-Income Countries: Findings from the Study on global AGEing and adult health (SAGE)

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Objectives: Changes in sleep patterns often occur in older adults. Previous studies have documented associations between sleep duration, sleep quality, and obesity risk in older individuals, yet few studies have examined these trends in lower-income countries. The present cross-sectional study uses nationally representative datasets from six countries to examine these relationships.

Methods: Two hypotheses related to obesity risk and sleep patterns were tested using data from the first wave of the World Health Organization's Study on global AGEing and adult health (SAGE). This longitudinal study draws on samples of older adults (>50 years old) in six middle-income countries (China, Ghana, India, Mexico, Russian Federation, and South Africa). Self-report data were used to measure sleep duration, sleep quality, lifestyle and sociodemographic information, while anthropometric measurements were collected to assess body mass index (BMI) and waist circumference (WC). Multiple linear regressions were used to examine the relationship between sleep patterns and obesity risk while controlling for lifestyle factors.

Results: Shorter sleep durations in both men and women were significantly associated with higher BMI and WC measures ($P < 0.05$). Low sleep quality did not significantly contribute to increased obesity risk. Surprisingly, high sleep quality was significantly associated with increased male BMI and WC in China and India ($P < 0.01$).

Conclusions: This study documented an association between short sleep duration and increased obesity risk, which is important given the global increase of obesity-related diseases. Am. J. Hum. Biol. 00:000–000, 2014.

Global obesity rates have risen significantly in all age groups over the past decade, increasing the associated disease prevalence and strains on health care systems (Chen et al., 2012; Hossain et al., 2007; Lakdawalla et al., 2005). Interventions designed to mitigate the prevalence of obesity are urgently needed to reduce this burden and its associated economic cost (López-García et al., 2008). Previous studies have demonstrated a link between sleep patterns, physiological processes, and obesity risk (Knutson and Van Cauter, 2008; Spiegel et al., 2004; Taheri et al., 2004; Tsou, 2011). Recent findings among children and younger adults suggest that improving sleep patterns represent a promising obesity prevention strategy; however, this is poorly tested among older adults, with available studies producing rather mixed results (Gangwisch et al., 2005; López-García et al., 2008; Patel and Hu, 2008; Spiegel et al., 2009; Van den Berg et al., 2008). This is particularly important for older adults in whom alterations in sleep duration and quality are more common, including an increased occurrence of reported sleep disorders associated with disrupted and fragmented sleep patterns (Bombois et al., 2010; Descamps and Cespuglio, 2010). These changes may contribute to obesity among older individuals; yet the majority of research on this topic has taken place in wealthy nations, and these patterns remain poorly understood in developing countries.

Short sleep durations have been linked with increased obesity risk, likely due to changes in the secretion of hormones known to regulate hunger and satiety (Patel et al., 2008; Tsou, 2011; Van den Berg et al., 2008). Sleep-restricted individuals exhibit elevated levels of serum ghrelin (an appetite stimulant) and reduced levels of serum leptin (a satiety factor) (Gangwisch et al., 2005; Knutson and Van Cauter, 2008; Patel and Hu, 2008; Spiegel et al., 2004, 2009; Taheri et al., 2004). These changes increase perceived hunger, especially for calorie-dense foods with high carbohydrate content (Spiegel et al., 2004). Thus, short sleep durations appear to alter endocrine function in a manner that facilitates weight gain.

Reduced sleep has likewise been linked with decreased physical activity, also thought to contribute to increased weight gain (Knutson and Van Cauter, 2008). Specifically, sleep deprivation has been shown to decrease the time to exhaustion during prolonged treadmill walking (Martin, 1981; Van Helder and Radomski, 1989) and increase ratings of perceived exercise exertion although physiological parameters do not significantly change (Martin and Gaddis, 1981; Myles, 1985; Van Helder and Radomski, 1989). Some researchers have further posited that individuals who sleep less have more time to eat, resulting in further increases in body weight (Magee et al., 2010).

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Fragmented sleep and lower subjective sleep quality scores have also been linked with higher BMI and obesity rates (Spiegel et al., 2009; Van den Berg et al., 2008; Vogontzas et al., 1997). Obesity may predispose individuals to sleep disruptions, such as sleep apnea through the narrowing of the upper airway (Wolkove et al., 2007). In addition, disrupted sleep cycles often reduce the amount of restorative slow-wave sleep (SWS) (Spiegel et al., 2009). SWS appears to influence endocrine activity. For instance, growth hormone (GH) secretion is stimulated during sleep (Van Cauter et al., 1998, 2000). Conversely, the hypothalamic-pituitary-adrenal (HPA) axis, which regulates the release of cortisol, is inhibited during early SWS (Gronfier et al., 1997; Spath-Schwalbe et al., 1993, 1994; Weitzman et al., 1983). Sleep patterns therefore strongly impact the production of these hormones, and abnormal sleep cycles have been shown to diminish the characteristic circadian rhythms of cortisol release and decrease nocturnal GH pulses (Van Cauter et al., 1991). Furthermore, both cortisol and growth hormone typically counteract the effects of insulin by inhibiting the removal of glucose from circulation; it is therefore likely that decreased sleep quality and disrupted sleep cycles can modify energy mobilization patterns (e.g., alter glucose regulation), thereby increasing obesity risk.

Cross-cultural studies are urgently needed to distinguish which obesity risk factors represent biological determinants shared between populations and which are strongly influenced by behavioral and environmental factors. This information is critical, since the development of effective obesity prevention strategies relies upon understanding how culturally influenced factors (e.g., activity levels, sleep patterns, etc.) are related to increasing obesity rates. To date, most sleep-obesity research has relied upon data drawn from high-income nations, highlighting patterns that may differ from less economically developed countries. Assessing the association between sleep variables and obesity levels among lower income populations is therefore essential.

The present study addresses this need by using cross-cultural data from the first wave of the World Health Organization's Study on global AGEing and adult health (SAGE) to examine links between sleep and obesity patterns. Data from six middle-income countries (China, Ghana, India, Mexico, Russian Federation, and South Africa) are used to construct a comprehensive picture of how sleep patterns and obesity among older adults vary across lower income countries. Two hypotheses are tested: 1) Short sleep durations will be positively associated with obesity; and, 2) Higher subjective sleep quality ratings will be inversely related to obesity risk.

METHODS

Ethical approval

SAGE was approved by the World Health Organization's Ethical Review Committee. Additionally, partner organizations in each country implementing SAGE obtained ethical clearance through their respective institutional review bodies. Informed consent was obtained from all study participants.

Study design and participants

Nationally representative samples of older adults (>50 years old) were drawn from each participating SAGE country (Kowal et al., 2012). Sampling in each country was based on a stratified multistage cluster sample design. Strata were uniquely defined for each country to ensure the full range of living conditions in that nation were represented in the study (Naidoo, 2012). Face-to-face interviews were used to collect household and individual level data.

Sleep variables

During the face-to-face interview, participants were asked how many hours they slept on each of the preceding two nights. In accordance with other sleep studies, the duration values across two nights were averaged together to create a summary measure of sleep length (Faubel et al., 2009; Patel et al., 2006). Participants were then asked to rate their sleep quality for each night based on a whole number scale of 1 to 5 (1 = very good quality, 5 = very poor quality); these results were reverse coded so that a higher rating corresponded with good quality sleep and a lower rating represented poor quality sleep. The quality values were then averaged to compute the typical sleep quality for each individual. The sleep duration and quality measures did not include daytime sleep.

Obesity risk measures

Obesity levels were assessed with two measurements. Height (cm) and weight (kg) of each participant were measured during the interview process; these values were then used to calculate body mass index (BMI; kg/m^2). WHO (2000) classifications were used for BMI categories: underweight (<18.5 kg/m^2), normal (18.5–24.9 kg/m^2), overweight (25.0–29.9 kg/m^2), and obese (≥30 kg/m^2). Since the relationships among BMI, body fat percentage, and health risk are different in Asian populations compared to other groups, modified BMI cut-offs for China and India were used: underweight (<18.5 kg/m^2), normal (18.5–22.9 kg/m^2), increased risk (23.0–27.5 kg/m^2), and higher high risk (≥27.5 kg/m^2) (WHO, 2004).

WHO (2011) recommendations were used for categorizing health risk from waist circumference measurements (WC): normal (<94 cm) and increased risk of cardiovascular disease and diabetes (>94 cm) for males, and normal (<80 cm) and increased risk (>80 cm) for females. Modified WC cut-offs were used for China and India; however, these revised categories only adjust the risk classifications for males: normal (<90 cm) and increased risk (>90 cm) (IDF, 2006). These BMI and WC categories were used to assess obesity prevalence in each participant country.

Extreme outliers were identified with interquartile ranges (IQRs) by sex, age, and country following Larson (2006; if $x < Q1 - 3 \times IQR$ or $x > Q3 + 3 \times IQR$). All analyses were conducted separately for BMI and WC, and outliers were removed before statistical tests. These outliers were most likely a result of measurement or data entry errors and account for less than one percent of the total sample. Given the total sample size, the overall impact of removing the outliers is minimal and provides a more accurate population estimate.

Lifestyle factors

To control for potential confounding lifestyle factors, a variety of health measures were considered. Smoking and drinking frequency were reported during the face-to-face interview, and individuals were sorted into categories based on these responses. Smoking categories were defined as "not at all," "occasionally," and "daily," while drinking categories included "not at all," "occasionally" (<3 days per month), and "moderate/heavy drinker" (>1 days per week). These variables were dummy coded using the "not at all" category as the reference group. In addition, average participant blood pressure was included in the analyses. Systolic (SBP) and diastolic blood pressure (DBP) were each measured three times. The three SBP values were averaged together to create a composite SBP measure; similarly, the three DBP values were combined to create an average DBP measure. High blood pressure is associated with higher body weight (Mokdad et al., 2003; Must et al., 1999), increased sleep disturbances (Ekstedt et al., 2004), and elevated risk of sleep apnea (Lauderdale et al., 2006). Thus, to control for the potential association between blood pressure and obesity risk, systolic and diastolic blood pressure were included as potential confounders.

Total physical activity level (PAL) was also calculated from interview data and included as a covariate to account for the influence of activity patterns on obesity risk. Specifically, questions from the Global Physical Activity Questionnaire (GPAQ) were utilized in SAGE to determine self-report physical activity patterns. This questionnaire is designed to collect information about physical activity patterns in different daily activities (Armstrong and Bull, 2006; Bull et al., 2009). For example, participants were asked to report the number of hours during a typical day they spent in vigorous-intensity activities as part of their work, in moderate-intensity activities as part of their work, in vigorous-intensity activities during leisure time, and in moderate-intensity activities during leisure time. Vigorous-intensity activities were defined as those that caused large increases in breathing or heart rate (e.g., heavy lifting, digging, or chopping wood), while moderate-intensity activities were defined as those that caused small increases in breathing or heart rate. Self-reported time spent in vigorous or moderate exercise for both work and leisure were averaged together to create a composite PAL measure (hours/day). Finally, clinically depressed individuals were excluded from all analyses. Disturbed sleep is a hallmark of depression (Patel et al., 2006; Roberts et al., 2000; van den Burg et al., 1975). Therefore, to clarify how sleep patterns influence obesity risk in healthy individuals, 8,971 participants who reported depression diagnosis by a medical professional or who were missing responses were excluded from the present study.

Statistical analyses

Tests for normality were performed, and no violations were observed. Parametric tests were subsequently conducted using SPSS version 20 to test the hypotheses, and results were regarded as significant at $P < 0.05$.

Descriptive statistics. Weighted prevalence measures for the categorical BMI and WC variables were calculated by age category and sex for each country using the Complex Samples module in SPSS. For each participant country, individual weights were calculated at the person-level based on the selection probability at each stage of selection (Naidoo, 2012). For China, individual weights were post-stratified by province, sex and age groups (18–49, 50–59, 60–69, 70+) according to the 2008 population projections provided by China CDC and weight up to the total number of persons aged 18+. In Ghana, individual weights were post-stratified by region, locality, sex and age-groups (18–49, 50–59, 60–69, 70+) according to the 2009 projected population estimates provided by Stats Ghana. Individual weights in India were post-stratified by the six states, locality, sex and age-groups (18–49, 50–59, 60–69, 70+) according to the 2006 projected population estimates. For Mexico, individual weights were post-stratified by sex and age-groups (18–34, 35–49, 50–59, 60–105) according to the 2009 population census projections. Individual weights for the Russian Federation were poststratified by federal district, locality, sex and age-groups (18–49, 50–59, 60–69, 70+) according to the 2011 mean predictive population estimates provided by Russian Federal State Statistics Service. In South Africa, individual weights were post-stratified by province, sex and age-groups (18–49, 50–59, 60–69, 70+) according to the 2009 Medium Mid-Year population estimates from Statistics South Africa.

Examination of the relative contribution of sleep duration and sleep quality to BMI and WC variation. A series of linear regressions were conducted to test the hypotheses and evaluate the relative contribution of country and sleep patterns to obesity risk variation, while controlling for lifestyle factors. Preliminary χ^2 analyses indicated that sex differences in BMI and WC prevalence were apparent in all countries. In addition, significant sex differences in sleep patterns have been observed in each country (Gildner et al., 2014). Thus, following a standard approach (Lovejoy and Sainsbury, 2009), all analyses were run separately by sex.

Smoking and drinking frequency dummy codes, average SBP and DBP, and total PAL were included in the first step of all linear regression analyses to control for the contribution of these measures to variation in obesity risk. The six country categories were dummy coded using India as the reference group (because this country had the lowest BMI and WC averages). The country dummy codes were entered in the second step of the regressions to determine if participant country significantly contributed to variation in BMI and WC levels, and to control for these associations.

Hypothesis 1—Short sleep durations will be associated with greater obesity risk. Linear regressions were used to examine if average sleep duration contributed to variation in BMI or WC among older adults. BMI and WC as continuous variables were used in all models. Sleep duration was entered in the third step of these models.

Hypothesis 2—Higher subjective sleep quality ratings will be related to lower obesity risk. A second set of regressions were conducted to estimate the relative contribution of sleep quality to BMI or WC (as continuous variables). Sleep quality was entered in the third step of these models.

RESULTS

Descriptive statistics

BMI and WC measures by sex and country. Among men, major differences existed between countries in prevalence of underweight (from 0.5% in Mexican men to 39.3% in Indian men) and obesity/high-risk (from 4.0% in Indian

TABLE 1. Body mass index (BMI; kg/m²) category prevalence data for men, women, and sexes combined in each country with sample size (n)

	Underweight, as % (n = 3,082)	Normal, as % (n = 10,971)	Overweight/increased risk, as % (n = 9,654)	Obese/higher risk, as % (n = 5,273)
China total	4.2 (541)	38.0 (4,680)	42.7 (5,049)	15.1 (1,601)
Men	4.2 (247)	42.0 (2,397)	42.4 (2,348)	11.4 (570)
Women	4.3 (294)	34.1 (2,283)	42.9 (2,701)	18.6 (1,031)
Ghana total	14.8 (562)	55.7 (2,139)	19.8 (725)	9.7 (343)
Men	14.8 (300)	60.5 (1,261)	18.6 (352)	6.1 (102)
Women	14.8 (262)	50.2 (878)	21.2 (373)	13.9 (241)
India total	38.4 (1,800)	39.3 (2,140)	15.7 (933)	6.6 (376)
Men	39.3 (951)	41.6 (1,179)	15.1 (465)	4.0 (116)
Women	37.4 (849)	36.9 (961)	16.4 (468)	9.3 (260)
Mexico total	0.6 (18)	21.6 (477)	48.7 (709)	29.0 (544)
Men	0.5 (6)	20.7 (220)	57.2 (336)	21.6 (161)
Women	0.8 (12)	22.6 (227)	39.7 (373)	36.9 (383)
Russia total	1.1 (26)	23.9 (692)	40.6 (1,288)	34.3 (1,016)
Men	1 (9)	27.6 (313)	46.2 (564)	25.1 (226)
Women	1.2 (17)	21.3 (379)	36.5 (724)	40.9 (790)
South Africa total	3.3 (135)	22.8 (843)	26.9 (950)	47.1 (1,393)
Men	4.1 (73)	28.0 (443)	28.5 (429)	39.4 (476)
Women	2.6 (62)	18.6 (400)	25.6 (521)	53.1 (917)

BMI categories are defined as: underweight (<18.5 kg/m²), normal (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30 kg/m²) in non-Asian populations and underweight (<18.5 kg/ m²), normal (18.5–22.9 kg/ m²), increased risk (23.0–27.5 kg/ m²), and higher high risk (≥27.5 kg/ m²) in Asian populations.

men to 39.4% in South African men) (see Table 1). There was also substantial variation between countries in the prevalence of individuals in the increased risk WC category (17.1% in men from Ghana to 62.2% in Mexican men) (see Table 2). Women also exhibited major differences between countries in prevalence of underweight (from 0.8% in Mexican women to 37.4% in Indian women) and obesity/high risk (from 8.8% in India to 51.0% in South Africa) (see Table 1). Furthermore, women displayed variability in prevalence of individuals in the increased risk WC category (53.1% in India to 89.7% in Mexico) (see Table 2).

Association between sleep duration and obesity risk measures by sex

Linear regressions were used to assess the contribution of sleep duration to BMI variation while controlling for lifestyle factors and country (see Table 3). In men pooled from all countries, lifestyle measures explained a significant amount of the variance in BMI ($R^2 = 0.107$, $P < 0.001$). Adding the country dummy codes explained a significant amount of additional BMI variation (R^2 change = 0.197, $P < 0.001$), indicating that participant country significantly contributed to BMI variation. Compared to India, men in the other countries had significantly higher BMI ($P < 0.001$). Adding sleep duration explained a moderate yet significant amount of additional variance (R^2 change = 0.003, $P < 0.001$). Specifically, longer sleep durations were significantly associated with lower BMI measures ($\beta = -0.058$; $P < 0.001$); although this effect is small, the relationship was statistically significant in part because of the large sample size.

Linear regressions were also conducted for women pooled from all countries (see Table 3). Again, lifestyle measures explained a significant amount of the variance in BMI ($R^2 = 0.111$, $P < 0.001$). Adding the country dummy codes explained a significant amount of additional variation in BMI (R^2 change = 0.144, $P < 0.001$), with women in all countries exhibiting significantly higher BMI values compared to India ($P < 0.05$). Adding sleep duration explained a moderate yet significant amount of additional variance (R^2 change = 0.005, $P = 0.039$); specifically, longer sleep durations were significantly associated with lower BMI measures ($\beta = -0.076$; $P = 0.039$).

The linear regression examining the contribution of sleep duration to variation in WC for men indicated that lifestyle factors explained a significant amount of the variance in WC ($R^2 = 0.090$, $P < 0.001$) (see Table 4). Adding the country dummy codes explained a significant amount of additional variation in WC (R^2 change = 0.133, $P < 0.001$); men in all the countries except Ghana displayed significantly higher WC measures compared to India ($P < 0.01$). Adding average sleep duration explained a significant amount of additional variance (R^2 change = 0.004, $P < 0.001$), in which WC decreased significantly as sleep duration increased ($\beta = -0.063$; $P < 0.001$). Again, this very small but statistically significant result is in part a result of the large sample size.

The results of the linear regression examining the contribution of sleep duration to variation in WC for women indicated that lifestyle factors explained a significant amount of the variance in WC ($R^2 = 0.064$, $P < 0.001$) (see Table 4). Adding the country dummy codes explained a significant amount of additional variation in WC (R^2 change = 0.091, $P < 0.001$); women in all the countries exhibited significantly higher WC measures when compared to India ($P < 0.05$). Finally, adding average sleep duration explained a significant amount of additional variance in WC (R^2 change = 0.006, $P = 0.030$). Longer sleep durations were significantly associated with lower measures of WC ($\beta = -0.086$; $P = 0.030$).

Associations between sleep quality and obesity risk measures by sex

Linear regressions were conducted to assess the contribution of self-reported sleep quality to BMI variation while controlling for lifestyle factors and country. In men pooled from all countries, lifestyle measures explained a significant amount of the variance in BMI ($R^2 = 0.111$, $P < 0.001$) (see Table 3). Adding the country dummy codes explained a significant amount of additional variation in BMI (R^2 change = 0.198, $P < 0.001$): compared to India,

TABLE 2. Waist circumference (WC; cm) category prevalence data for men, women, and sexes combined in each country with sample size (n)

	Normal, as % (n = 13,862)	Increased risk, as % (n = 14,855)
China total	51.2 (6,081)	48.8 (5,886)
Men	70.7 (3,963)	29.8 (1,651)
Women	31.9 (2,118)	68.1 (4,235)
Ghana total	59.7 (2,297)	40.3 (1,480)
Men	82.9 (1,721)	17.1 (299)
Women	32.6 (576)	67.4 (1,181)
India total	63.8 (3,308)	36.2 (1,976)
Men	79.5 (2,128)	20.5 (595)
Women	46.9 (1,180)	53.1 (1,381)
Mexico total	24.4 (342)	75.6 (1,395)
Men	37.8 (248)	62.2 (480)
Women	10.3 (94)	89.7 (915)
Russia total	31.9 (694)	68.1 (1,983)
Men	46.9 (436)	53.1 (491)
Women	21.9 (258)	78.1 (1,492)
South Africa total	34.9 (1,140)	65.1 (2,135)
Men	53.9 (776)	46.1 (624)
Women	20.0 (364)	80.0 (1,511)

In non-Asian countries WC categories are defined as: normal (≤94 cm) and increased risk (>94 cm) for males, and normal (<80 cm) and increased risk (>80 cm) for females. In Asian countries WC categories are defined as: normal (<90 cm) and increased risk (>90 cm) for males, and normal (<80 cm) and increased risk (>80 cm) for females.

men in the other countries had significantly higher BMI ($P < 0.01$). Adding average sleep quality explained a significant amount of additional variance (R^2 change = 0.002, $P = 0.001$); specifically, higher sleep quality ratings were significantly associated with higher BMI measures ($\beta = 0.042$; $P = 0.001$). However, when examined by country, this significant positive relationship between sleep quality and BMI was only apparent in men from India ($P < 0.001$) and China ($P = 0.001$), indicating that cultural factors may account for this unexpected trend.

Similarly, lifestyle measures explained a significant amount of the variance in the BMI measures of women ($R^2 = 0.121$, $P < 0.001$) (see Table 3). Adding the country dummy codes explained a significant amount of additional variation in BMI (R^2 change = 0.156, $P < 0.001$); women in all countries had significantly higher BMI values when compared to India ($P < 0.05$). Adding sleep quality did not explain a significant amount of additional variance in the model (R^2 change = 0.000, $P = 0.804$).

Linear regressions were also used to examine the contribution of sleep quality to WC variation for men (see Table 4). This analysis indicated that lifestyle factors explained a significant amount of the variance in male WC ($R^2 = 0.094$, $P < 0.001$). Adding the country dummy codes explained a significant amount of additional variation in WC (R^2 change = 0.136, $P < 0.001$); men in all the countries except Ghana displayed significantly higher WC measures compared to India ($P < 0.01$). Adding average sleep quality explained a significant amount of additional variance (R^2 change = 0.002, $P = 0.001$); WC increased significantly as sleep quality ratings increased ($\beta = -0.044$; $P = 0.001$). However, when examined by country, only men in India ($P = 0.001$) and China ($P < 0.001$) displayed this significant association; this again suggests that cultural factors may account for this surprising pattern.

The results of the linear regression examining the contribution of average sleep quality ratings to WC variation in women indicated that lifestyle factors explained a significant amount of the variance in WC ($R^2 = 0.077$, $P < 0.001$) (see Table 4). Adding the country dummy codes explained a significant amount of additional variation in WC (R^2 change = 0.095, $P < 0.001$); women in all the countries except Ghana exhibited significantly higher WC measures compared to women in India ($P < 0.05$). Adding average sleep quality did not explain a significant amount of additional WC variance in the model (R^2 change = 0.001, $P = 0.439$).

DISCUSSION

This study provides a unique examination of the interactions between sleep quality, duration, and obesity risk in older individuals. Previous research investigating these variables have been restricted to high-income countries, and several large cross-sectional studies in the US have documented a U-shaped relationship (Kripke et al., 2002; Singh et al., 2005; Taheri et al., 2004) or negative linear relationship (Gangwisch et al., 2005) between sleep duration and BMI. This suggests that sleep patterns and obesity levels may influence each other. The SAGE study offers a distinctive opportunity to further test these associations using a large sample drawn from several diverse nations; further, this sample is representative of the range of living conditions in each country.

The present study found support for one of the two hypotheses. As expected, shorter sleep durations were significantly associated with higher BMI and WC measures for both men and women. Both BMI and WC measures were lower at longer sleep durations. However, the results did not support the hypotheses that poor sleep quality would significantly contribute to patterns in obesity risk.

Sleep duration and obesity risk.

The relative contribution of sleep duration to obesity risk was rather low compared to several other factors included in the linear regression models (e.g., participant country, blood pressure measures, and smoking level) (see Tables 3 and 4). Still, the present study did document a significant inverse relationship between sleep duration and obesity risk that is consistent with research examining smaller samples from high-income countries. These previous studies indicate that sleep deprivation alters hormone secretion levels, thus affecting obesity risk. These changes result in appetite stimulation and satiation repression, increasing the frequency and portion size of food consumed (Knutson and Van Cauter, 2008; Patel and Hu, 2008). However, the directionality of the relationship between short sleep duration and increased obesity rates is unclear. Previous findings indicate that obese individuals are more likely to be diagnosed with sleep apnea, a condition characterized by the repeated cessation of breathing during sleep (Vgontzas et al., 2000). This condition is caused by a collapse of the throat, a process often exacerbated by excess weight (Dement, 1999). Thus, obesity-induced sleep apnea may result in short sleep durations, daytime fatigue, and reduced activity levels. Therefore, while short sleep durations may increase obesity risk, excess weight can also impair sleep patterns. This may result in a circular pattern in which sleep patterns and body composition continually affect one another and further deteriorate. Longitudinal studies are needed to further elucidate the directionality of these complex interactions.

TABLE 3. Multiple regression models for prediction of BMI (populations combined)[a,b]

Variable	Coefficients (SE)	β	P	Model r^2 and P
Sleep duration (hr/night)				
Men				
BMI (kg/m^2)				0.31/<0.001***
Constant	18.246 (0.445)		<0.001	
Average systolic blood pressure	0.029 (0.003)	0.158	<0.001	
Average diastolic blood pressure	0.003 (0.005)	0.010	=0.573	
Total physical activity level	−0.018 (0.014)	−0.016	=0.190	
Smoking				
Occasionally	−0.362 (0.215)	−0.022	=0.092	
Daily	−1.031 (0.132)	−0.113	<0.001	
Drinking				
Occasionally	0.065 (0.150)	0.007	=0.667	
Moderate/heavy drinker	−0.385 (0.158)	−0.043	=0.014	
Country				
Mexico	6.190 (0.252)	0.377	<0.001	
Ghana	0.926 (0.226)	0.067	<0.001	
China	2.819 (0.169)	0.323	<0.001	
South Africa	4.504 (0.261)	0.258	<0.001	
Russia	6.396 (0.208)	0.497	<0.001	
Average sleep duration	−0.165 (0.035)	−0.058	<0.001	
Women				
BMI (kg/m^2)				0.24/=0.039*
Constant	16.025 (2.141)		<0.001	
Average systolic blood pressure	0.014 (0.013)	0.052	=0.293	
Average diastolic blood pressure	0.057 (0.022)	0.136	=0.012	
Total physical activity level	0.005 (0.076)	0.002	=0.952	
Smoking				
Occasionally	−1.491 (0.777)	−0.072	=0.055	
Daily	−1.578 (0.559)	−0.115	=0.005	
Drinking				
Occasionally	0.822 (0.664)	0.060	=0.216	
Moderate/heavy drinker	−0.572 (0.783)	−0.035	=0.465	
Country				
Mexico	9.604 (1.195)	0.491	<0.001	
Ghana	2.926 (1.190)	0.123	=0.014	
China	4.550 (1.088)	0.238	<0.001	
South Africa	7.437 (1.002)	0.504	<0.001	
Russia	8.752 (1.011)	0.542	<0.001	
Average sleep duration	−0.324 (0.157)	−0.076	=0.039	
Sleep quality (average rating of two previous nights on scale 1–5)				
Men				
BMI (kg/m^2)				0.31/=0.001**
Constant	16.293(0.454)		<0.001	
Average systolic blood pressure	0.028 (0.003)	0.149	<0.001	
Average diastolic blood pressure	0.004 (0.005)	0.013	=0.422	
Total physical activity level	−0.020 (0.014)	−0.017	=0.149	
Smoking				
Occasionally	−0.361 (0.210)	−0.022	=0.085	
Daily	−1.073 (0.128)	−0.118	<0.001	
Drinking				
Occasionally	0.061 (0.147)	0.007	=0.679	
Moderate/heavy drinker	−0.412 (0.154)	−0.046	=0.008	
Country				
Mexico	6.023 (0.250)	0.363	<0.001	
Ghana	0.735 (0.212)	0.056	=0.001	
China	2.778 (0.167)	0.318	<0.001	
South Africa	4.187 (0.251)	0.238	<0.001	
Russia	6.312 (0.203)	0.501	<0.001	
Average sleep quality	0.250 (0.072)	0.042	=0.001	
Women				0.26/=0.804
BMI (kg/m^2)				
Constant	14.588 (2.078)		<0.001	
Average systolic blood pressure	0.013 (0.013)	0.048	=0.316	
Average diastolic blood pressure	0.051 (0.022)	0.121	=0.018	
Total physical activity level	0.028 (0.072)	0.014	=0.693	
Smoking				
Occasionally	−1.675 (0.746)	−0.080	=0.025	
Daily	−1.958 (0.533)	−0.142	<0.001	
Drinking				
Occasionally	0.785 (0.632)	0.057	=0.214	
Moderate/heavy drinker	−0.372 (0.737)	−0.023	=0.614	
Country				
Mexico	9.673 (1.172)	0.475	<0.001	
Ghana	2.183 (1.039)	0.110	=0.036	
China	4.578 (1.065)	0.232	<0.001	
South Africa	7.189 (0.972)	0.476	<0.001	
Russia	8.662 (0.993)	0.524	<0.001	
Average sleep quality	−0.074 (0.298)	−0.008	=0.804	

[a]Comparisons are statistically significant at: *$P<0.05$, **$P<0.01$, ***$P<0.001$.
[b]Reference groups used in the creation of dummy codes for each categorical variable:
i. Smoking levels = not at all.
ii. Drinking levels = not at all.
iii. Country = India.

TABLE 4. Multiple regression models for prediction of WC (populations combined)[a,b]

Variable	Coefficients (SE)	β	*p*	Model r^2 and *p*
Sleep duration (hr/night)				
Men				
WC (cm)				0.23/<0.001***
Constant	79.393 (1.359)		<0.001	
Average systolic blood pressure	0.075 (0.010)	0.141	<0.001	
Average diastolic blood pressure	−0.008 (0.015)	−0.009	=0.603	
Total physical activity level	−0.194 (0.043)	−0.059	<0.001	
Smoking				
Occasionally	−1.635 (0.664)	−0.034	=0.014	
Daily	−3.385 (0.405)	−0.129	<0.001	
Drinking				
Occasionally	0.658 (0.460)	0.026	=0.152	
Moderate/heavy drinker	−0.529 (0.482)	−0.021	=0.272	
Country				
Mexico	15.173 (0.769)	0.322	<0.001	
Ghana	−1.794 (0.690)	−0.045	=0.009	
China	1.620 (0.513)	0.064	=0.002	
South Africa	3.684 (0.792)	0.074	<0.001	
Russia	11.102 (0.659)	0.282	<0.001	
Average sleep duration	−0.512 (0.107)	−0.063	<0.001	
Women				
WC (cm)				0.16/=0.030*
Constant	74.034 (5.347)		<0.001	
Average systolic blood pressure	0.076 (0.033)	0.121	=0.022	
Average diastolic blood pressure	−0.002 (0.056)	−0.002	=0.967	
Total physical activity level	0.076 (0.191)	0.016	=0.690	
Smoking				
Occasionally	−1.708 (1.942)	−0.036	=0.379	
Daily	−1.444 (1.403)	−0.045	=0.304	
Drinking				
Occasionally	1.743 (1.662)	0.054	=0.294	
Moderate/heavy drinker	−0.738 (1.965)	−0.019	=0.707	
Country				
Mexico	19.240 (2.961)	0.423	<0.001	
Ghana	9.782 (2.957)	0.178	=0.001	
China	5.464 (2.695)	0.122	=0.043	
South Africa	12.324 (2.490)	0.356	<0.001	
Russia	15.426 (2.533)	0.400	<0.001	
Average sleep duration	−0.848 (0.390)	−0.086	=0.030	
Sleep quality (average rating of two previous nights on scale 1−5)				
Men				
WC (cm)				0.23/=0.001**
Constant	73.264 (1.388)		<0.001	
Average systolic blood pressure	0.071 (0.009)	0.132	<0.001	
Average diastolic blood pressure	−0.004 (0.015)	−0.004	=0.821	
Total physical activity level	−0.205 (0.042)	−0.062	<0.001	
Smoking				
Occasionally	−1.546 (0.651)	−0.032	=0.018	
Daily	−3.485 (0.394)	−0.132	<0.001	
Drinking				
Occasionally	0.679 (0.452)	0.026	=0.133	
Moderate/heavy drinker	−0.630 (0.473)	−0.025	=0.183	
Country				
Mexico	14.662 (0.763)	0.308	<0.001	
Ghana	−2.655 (0.646)	−0.071	<0.001	
China	1.493 (0.507)	0.059	=0.003	
South Africa	2.699 (0.764)	0.053	<0.001	
Russia	10.916 (0.642)	0.283	<0.001	
Average sleep quality	0.759 (0.220)	−0.044	=0.001	
Women				
WC (cm)				0.16/=0.439
Constant	67.438 (5.207)		<0.001	
Average systolic blood pressure	0.075 (0.032)	0.119	=0.020	
Average diastolic blood pressure	−0.005 (0.054)	−0.005	=0.923	
Total physical activity level	0.121 (0.182)	0.025	=0.508	
Smoking				
Occasionally	−2.617 (1.864)	−0.054	=0.161	
Daily	−2.862 (1.334)	−0.089	=0.032	
Drinking				
Occasionally	1.271 (1.578)	0.039	=0.421	
Moderate/heavy drinker	−0.823 (1.847)	−0.022	=0.656	
Country				
Mexico	18.175 (2.903)	0.388	<0.001	
Ghana	4.654 (2.578)	0.102	=0.071	

TABLE 4. Continued

Variable	Coefficients (SE)	β	p	Model r^2 and p
China	5.458 (2.637)	0.119	=0.039	
South Africa	10.644 (2.415)	0.302	<0.001	
Russia	14.973 (2.485)	0.382	<0.001	
Average sleep quality	0.581 (0.750)	0.028	=0.439	

[a]Comparisons are statistically significant at: $^*P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.
[b]Reference groups used in the creation of dummy codes for each categorical variable:
i. Smoking levels = not at all.
ii. Drinking levels = not at all.
iii. Country = India.

Sleep quality and obesity risk. Interestingly, the analyses did not demonstrate a significant association between low sleep quality and obesity risk; instead, it appears that increased sleep quality significantly contributed to higher BMI and WC values in men from certain countries. However, the contribution of sleep quality to obesity risk was small relative to many other factors included in the linear regression models (e.g., participant country, blood pressure measures, and smoking level) (see Tables 3 and 4). Furthermore, when examined by country, this significant positive relationship was only apparent in men from India and China. This unexpected pattern may therefore be the result of socioeconomic differences and living conditions in these two countries. Social factors like financial stress, health concerns, and an unfavorable work schedule (e.g., working the night shift) have been shown to negatively affect sleep quality (Lallukka et al., 2012; Mezick et al., 2008; Stamatakis et al., 2007). Economic infrastructure and occupation status therefore play an important role in shaping sleep patterns. It is possible that individuals of higher socioeconomic status (SES) are less exposed to these adverse social stressors and subsequently report higher sleep quality scores. However, wealthier individuals in these countries may also have increased access to market economy goods such as processed foods, and therefore demonstrate higher BMI and WC scores. Thus, it is possible that individuals of higher SES in India and China may report improved sleep quality while simultaneously exhibiting increased obesity rates; however, this remains to be tested.

Limitations

The present study has several important limitations. The sleep data used relied on self-report responses concerning sleep duration, yet it is often difficult for individuals to discern between time in bed and time asleep. Studies indicate that participants often report time in bed when asked how long they slept, thus overestimating time spent asleep (Stenholm et al., 2011). Objective measures based on polysomnography or actigraphy are recommended to more precisely record individual sleep patterns (e.g., sleep duration, transitions between sleep states, and duration of night awakenings) (Lockley et al., 2002). Thus, these objective sleep measures may further illuminate the relationship between sleep patterns and obesity risk. For example, a recent study by Mezick and colleagues found that actigraphy assessments of sleep were more strongly associated with body weight and WC than self-report. Both self-reported and actigraphy-assessed total sleep time in that study were more strongly associated with higher BMI in a combined sample of men and women (Mezick et al., 2014). Yet, when the analyses were stratified by gender, shorter actigraphy-assessed sleep was significantly associated with higher BMI and WC in women but not men. Actigraphy-assessed sleep efficiency also exhibited a significant inverse relationship with both BMI and WC in women but not men (Mezick et al., 2014). It is therefore possible that objective sleep measures may better capture the association between sleep quality and obesity risk, and may demonstrate that significant relationships between sleep patterns and obesity risk are more pronounced in women. However, objective sleep measures are typically more invasive and expensive, making it difficult to recruit the large nationally-representative samples required for cross-cultural comparisons. A second limitation is the dependence on data from only two nights of sleep; these values may not accurately characterize usual sleep patterns.

Further, it is possible that sleep apnea may underlie the observed associations between sleep and obesity. However, information on sleep apnea and other sleep disorders was not included in the SAGE participant questionnaire; it was therefore not possible to include sleep apnea as a possible confounder in this study. Still, a positive correlation has been documented between high blood pressure and risk of sleep apnea (Caples et al., 2007; Lauderdale et al., 2006). Sleep apnea appears to trigger an exaggerated peripheral chemoreflex response; this chemoreflex activation subsequently increases peripheral vascularization and elevates arterial blood pressure (Narkiewicz et al., 1999; Somers et al., 1995). Thus, inclusion of blood pressure as a confounder in the present analyses may have captured some of the contribution of cardiorespiratory conditions to variation in BMI and WC.

Finally, due to the cross-sectional nature of the data used in the present study, it is not possible to establish causality between variables. It is possible that the differences in obesity levels observed may not be due to deficient sleep patterns; instead, high BMI and WC levels in older individuals could result in short sleep duration. Longitudinal data following the progression of these trends over time is required to further parse out these interactions. SAGE is currently collecting a second wave of data on study participants, which will help address this issue. These data will also facilitate the examination of other issues such as undiagnosed illness, which could affect sleep and obesity risk, but would only be detected over long periods of time. These data could also be used to examine how cultural differences, individual SES, and living conditions (e.g., urban vs. rural) influence long-term health patterns. However, given the association between short sleep duration and increased obesity risk, the diagnosis of sleep disorders in older adults is an important consideration for the design and implementation of effective obesity prevention programs.

CONCLUSION

This study documented significant but modest relationships between sleep quantity and obesity risk among older individuals from six middle-income countries. These results support previous findings in high-income populations and suggest that longer sleep durations are associated with reduced obesity levels cross-culturally in diverse societies. Thus, increasing sleep duration in sleep-deprived individuals is an important consideration in future clinical studies aimed at decreasing obesity prevalence among older individuals.

This connection is especially relevant given the growing global rate of obesity and subsequent health conditions linked with excess weight (e.g., diabetes and cardiovascular disease). High obesity and overweight prevalence values have been documented in older adults over the age of 60 in several populations, including the US (33.8%) and Spain (31.5% of men and 40.8% of women); these values are expected to increase in coming years as populations continue to age (Flegal et al., 2010; Gutiérrez-Fisac et al., 2004). Diseases associated with excess weight gain have likewise demonstrated substantial increases in prevalence, a trend that is projected to continue in the future. The global prevalence of diabetes is expected to rise from 285 million to 439 million individuals by 2030, a 54% increase (Chen et al., 2012). Furthermore, substantial percentage increases in the number of diabetes cases have been projected in South Africa (98–162%), India (72–150%), and China (47–104%) by the year 2030 (Chen et al., 2012; Hossain et al., 2007). The largest increase in frequency of diabetes diagnoses is predicted to occur in individuals >65 years of age as a result of aging populations (Wild et al., 2004).

Furthermore, the global obesity pandemic is associated with considerable healthcare costs, especially among older individuals. In 2004, it was estimated that an obese 70-year-old member of the Medicare population accumulates $39,000 in additional medical costs compared to a non-obese peer (Lakdawalla et al., 2005). These costs will continue to rise in coming years as obesity prevalence increases. The implementation of effective programs to prevent obesity should therefore be prioritized; these interventions have the potential to reduce the global burden of chronic disease and save millions of dollars in healthcare spending. Thus, the modest yet significant contribution of sleep duration to variation in obesity risk documented in the present study suggests that interventions improving sleep patterns could potentially offer such an intervention. These interactions therefore deserve careful consideration in the design of future clinical interventions.

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LITERATURE CITED

Archer SN, Laing EE, Möller-Levet CS, van der Veen DR, Bucca G, Lazar AS, Santhi N, Slak A, Kabiljo R, von Schantz M, Smith CP, Dijk DJ. 2014. Mistimed sleep disrupts circadian regulation of the human transcriptome. Proc Natl Acad Sci USA 111:E682–E691.

Armstrong T, Bull F. 2006. Development of the World Health Organization global physical activity questionnaire (GPAQ). J Public Health 14:66–70.

Bombois S, Derambure P, Pasquier F, Monaca C. 2010. Sleep disorders in aging and dementia. J Nutr Health Aging 14:212–217.

Bull FC, Maslin TS, Armstrong T. 2009. Global physical activity questionnaire (GPAQ): nine country reliability and validity study. J Phys Act Health 6:790–784.

Caples SM, Garcia-Touchard A, Somers VK. 2007. Sleep-disordered breathing and cardiovascular risk. Sleep 30:291.

Chen L, Magliano DJ, Zimmet PZ. 2012. The worldwide epidemiology of type 2 diabetes mellitus—present and future perspectives. Nat Rev Endocrinol 8:228–236.

Dement WC, Vaughan C. 1999. The promise of sleep: a pioneer in sleep medicine explores the vital connection between health, happiness, and a good night's sleep. New York City, NY: Dell Publishing Co. p 168–170.

Descamps A, Cespuglio R. 2010. Influence of aging on the sleep rebound induced by immobilization stress in the rat. Brain Res 1335:14–23.

Ekstedt M, Åkerstedt T, Söderström M. 2004. Microarousals during sleep are associated with increased levels of lipids, cortisol, and blood pressure. Psychosom Med 66:925–931.

Flegal KM, Carroll MD, Ogden CL, Curtin LR. 2010. Prevalence and trends in obesity among US adults, 1999–2008. JAMA 303:235–241.

Gangwisch JE, Malaspina D, Boden-Albala B, Heymsfield SB. 2005. Inadequate sleep as a risk factor for obesity: analyses of the NHANES I. Sleep 28:1289.

Gildner TE, Liebert MA, Kowal P, Chatterji S, Snodgrass JJ. 2014. Associations between sleep duration, sleep quality: cognitive test performance among older adults from six middle income countries: Results from the Study on global AGEing and adult health (SAGE). J Clin Sleep Res 10: 613–621.

Gronfier C, Luthringer R, Follenius M, Schaltenbrand N, Macher JP, Muzet A, Brandenberger G. 1997. Temporal relationships between pulsatile cortisol secretion and electroencephalographic activity during sleep in man. EEG J 103:405–408.

Gutiérrez-Fisac JL, López E, Banegas JR, Graciani A, Rodríguez-Artalejo F. 2004. Prevalence of overweight and obesity in elderly people in Spain. Obes Res 12:710–715.

Hossain P, Kawar B, El Nahas M. 2007. Obesity and diabetes in the developing world—a growing challenge. N Engl J Med 356:213–215.

International Diabetes Federation (IDF). 2006. The IDF consensus worldwide definition of the metabolic syndrome. Available at: http://www.idf.org/webdata/docs/MetS_def_update2006.pdf. Accessed on March 26, 2014.

Knutson KL, Van Cauter E. 2008. Associations between sleep loss and increased risk of obesity and diabetes. Ann NY Acad Sci 1129:287–304.

Kowal P, Chatterji S, Naidoo N, Biritwum R, Fan W, Ridaura RL, Maximova T, Arokiasamy P, Phaswana-Mafuya N, Williams S, Snodgrass JJ, Minicuci N, D'Este C, Peltzer K, Boerma JT. 2012. Data resource profile: The WHO Study on Global Ageing and Adult Health (SAGE). Int J Epidemiol 2012 41:1639–1649.

Kripke DF, Garfinkel L, Wingard DL, Klauber MR, Marler MR. 2002. Mortality associated with sleep duration and insomnia. Arch Gen Psychiatry 59:131–136.

Lakdawalla DN, Goldman D, Shang B. 2005. The health and cost consequences of obesity among the future elderly. Health Aff (Millwood) 24(Suppl 2):W5R30–W5R41.

Lallukka T, Ferrie JE, Kivimäki M, Shipley MJ, Rahkonen O, Lahelma E. 2012. Economic difficulties and subsequent sleep problems: Evidence from British and Finnish occupational cohorts. Sleep Med 13:680–685.

Larson MG. 2006. Descriptive statistics and graphical displays. Circulation 114:76–81.

Lauderdale DS, Knutson KL, Yan LL, Rathouz PJ, Hulley SB, Sidney S, Liu K. 2006. Objectively measured sleep characteristics among early-middle-aged adults the CARDIA study. Am J Epidemiol 164:5–16.

Lockley SW, Skene DJ, Arendt J. 2002.Comparison between subjective and actigraphic measurement of sleep and sleep rhythms. J Sleep Res 8:175–183.

López-García E, Faubel R, León-Muñoz L, Zuluaga MC, Banegas JR, Rodríguez-Artalejo F. 2008. Sleep duration, general and abdominal obesity, and weight change among the older adult population of Spain. Am J Clin Med 87:310–316.

Lovejoy JC, Sainsbury A. 2009. Sex differences in obesity and the regulation of energy homeostasis. Obes Rev 10:154–167.

Magee CA, Huang XF, Iverson DC, Caputi P. 2010. Examining the pathways linking chronic sleep restriction to obesity. J Obes 2010:821710.

Martin BJ, Gaddis GM. 1980. Exercise after sleep deprivation. Med Sci Sports Exerc 13:220–223.

Martin BJ. 1981. Effect of sleep deprivation on tolerance of prolonged exercise. Eur J Appl Physiol 47:345–354.

Mezick EJ, Matthews KA, Hall M, Strollo PJ, Buysse DJ, Kamarck TW, Owens JF, Reis SE. 2008. Influence of race and socioeconomic status on sleep: Pittsburgh SleepSCORE project. Psychosom Med 70:410–416.

Mezick EJ, Wing RR, Hall M, McCaffrey JM. 2014. Associations of self-reported and actigraphy-assessed sleep characteristics with body mass index and waist circumference in adults: moderation by gender. Sleep Med 15:64–70.

Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, Bales VS, Marks JS. 2003. Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. JAMA 289:76–79.

Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. 1999. The disease burden associated with overweight and obesity. JAMA 282: 1523–1529.

Myles WS. 1985. Sleep deprivation, physical fatigue, and the perception of exercise intensity. Med Sci Sports Exerc 17:580–584.

Naidoo N. 2012. SAGE Working Paper No. 5 WHO Study on global AGEING and adult health (SAGE) Waves 0 and 1—sampling information for China, Ghana, India, Mexico, Russia, and South Africa. Retrieved from the World Health Organization Study on global AGEing and adult health (SAGE) website: http://www.who.int/healthinfo/sage/SAGEWorkingPaper5_Wave1Sampling.pdf?ua=1. Accessed on April 14, 2014.

Narkiewicz K, van de Borne PJ, Pesek CA, Dyken ME, Montano N, Somers VK. 1999. Selective potentiation of peripheral chemoreflex sensitivity in obstructive sleep apnea. Circulation 99:1183–1189.

Patel SR, Blackwell T, Redline S, Ancoli-Israel S, Cauley JA, Hillier TA, Lewis CE, Orwoll ES, Stefanick ML, Taylor BC, Yaffe K, Stone KL. 2008. The association between sleep duration and obesity in older adults. Int J Obes 32:1825–1834.

Patel SR, Hu FB. 2008. Short sleep duration and weight gain: a systematic review. Obesity 16:643–653.

Roberts RE, Shema SJ, Kaplan GA, Strawbridge WJ. 2000. Sleep complaints and depression in an aging cohort: a prospective perspective. Am J Psychiatry 157:81–88.

Singh M, Drake CL, Roehrs T, Hudgel DW, Roth T. 2005. The association between obesity and short sleep duration: a population-based study. JCSM 1:357–363.

Somers VK, Dyken ME, Clary MP, Abboud FM. 1995. Sympathetic neural mechanisms in obstructive sleep apnea. J Clin Invest 96:1897.

Späth-Schwalbe E, Uthgenannt D, Voget G, Kern W, Born J, Fehm HL. 1993. Corticotropin-releasing hormone-induced adrenocorticotropin and cortisol secretion depends on sleep and wakefulness. J Clin Endocrinol Met 77:1170–1173.

Späth-Schwalbe E, Uthgenannt D, Körting N, Fehm HL, Born J. 1994. Sleep and wakefulness affect the responsiveness of the pituitary-adrenocortical axis to arginine vasopressin in humans. Neuroendocrinology 60:544–548.

Spiegel K, Tasali E, Penev P, Van Cauter E. 2004. Brief communication: sleep curtailment in healthy young men is associated with decreased leptin levels, elevated ghrelin levels, and increased hunger and appetite. Ann Intern Med 141:846–850.

Spiegel K, Tasali E, Leproult R, Van Cauter E. 2009. Effects of poor and short sleep on glucose metabolism and obesity risk. Nat Rev Endocrinol 5:253–261.

Stamatakis KA, Kaplan GA, Roberts RE. 2007. Short sleep duration across income, education, and race/ethnic groups: population prevalence and growing disparities over 34 years of follow-up. Ann Epidemiol 17:948–955.

Stenholm S, Kronholm E, Bandinelli S, Guralnik JM, Ferrucci L. 2011. Self-reported sleep duration and time in bed as predictors of physical function decline: results from the InCHIANTI study. Sleep 34:1583–1593.

Taheri S, Lin L, Austin D, Young T, Mignot E. 2004. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. PLoS Med 1:e62.

Tsou MT. 2011. Association between sleep duration and health outcome in elderly Taiwanese. Int J Gerontol 5:200–205.

Van den Berg JF, Neven AK, Tulen JHM, Hofman A, Witteman JCM, Miedema HME, Tiemeier H. 2008. Actigraphic sleep duration and fragmentation are related to obesity in the elderly: the Rotterdam Study. Int J Obes 32:1083–1090.

Van Cauter E, Blackman JD, Roland D, Spire JP, Refetoff S, Polonsky KS. 1991. Modulation of glucose regulation and insulin secretion by circadian rhythmicity and sleep. J Clin Invest 88:934.

Van Cauter E, Plat L, Copinschi G. 1998. Interrelations between sleep and the somatotropic axis. Sleep 21:553–566.

Van Cauter E, Leproult R, Plat L. 2000. Age-related changes in slow wave sleep and REM sleep and relationship with growth hormone and cortisol levels in healthy men. JAMA 284:861–868.

Van den Burg W, van den Hoofdakker RH. 1975. Total sleep deprivation on endogenous depression. Arch Gen Psychiatry 32:1121–1125.

Van Helder T, Radomski MW. 1989. Sleep deprivation and the effect on exercise performance. Sports Med 7:235–247.

Vgontzas AN, Papanicolaou DA, Bixler EO, Hopper K, Lotsikas A, Lin HM, Kales A, Chrousos GP. 2000. Sleep apnea and daytime sleepiness and fatigue: relation to visceral obesity, insulin resistance, and hypercytokinemia. J Clin Endocrinol Metab 85:1151–1158.

Weitzman ED, Zimmerman JC, Czeisler CA, Ronda J. 1983. Cortisol secretion is inhibited during sleep in normal man. J Clin Endocrinol Met 56: 352–358.

World Health Organization (WHO). 2000. Obesity: preventing and managing the global epidemic. Geneva: World Health Organization.

World Health Organization (WHO). 2004. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. J Lancet 363:157–63.

World Health Organization (WHO). 2011. Waist circumference and waist-hip ratio: report of WHO pert consultation Geneva, 8–11, December 2008: World Health Organization.

Wild SH, Roglic G, Green A, Sicree R, King H. 2004. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030 response to Rathman and Giani. Diabetes Care 27:2569–2569.

Wolkove N, Elkholy O, Baltzan M, Palayew M. 2007. Sleep and aging: 1. Sleep disorders commonly found in older people. Can Med Assoc J 176: 1299–1304.