Sleep Duration and Quality: Impact on Lifestyle Behaviors and Cardiometabolic Health

A Scientific Statement From the American Heart Association

ABSTRACT: Sleep is increasingly recognized as an important lifestyle contributor to health. However, this has not always been the case, and an increasing number of Americans choose to curtail sleep in favor of other social, leisure, or work-related activities. This has resulted in a decline in average sleep duration over time. Sleep duration, mostly short sleep, and sleep disorders have emerged as being related to adverse cardiometabolic risk, including obesity, hypertension, type 2 diabetes mellitus, and cardiovascular disease. Here, we review the evidence relating sleep duration and sleep disorders to cardiometabolic risk and call for health organizations to include evidence-based sleep recommendations in their guidelines for optimal health.

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The ubiquity of public health reports touting the importance of sleep has led to an increased interest in understanding the extent of sleep problems at the population level and their associated negative effects on various cardiometabolic health outcomes. According to the National Heart, Lung, and Blood Institute of the National Institutes of Health, ≈50 to 70 million US adults suffer from a sleep disorder or report insufficient sleep habitually.[1] Although many individuals may opt to curtail their bedtime to pursue personal/professional goals or social obligations, a sizable portion may be experiencing sleep problems originating from a medical or psychosocial cause. Insomnia, the most common sleep disorder, is likely present in 5% to 15% of the US population, with ≈30% reporting significant symptoms at any given time.[2] Sleep apnea, another common sleep disorder defined as at least 5 respiratory events (apnea or hypopnea) per hour of sleep on average, has an estimated prevalence of 27% to 34% among men 30 to 70 years of age and 9% to 28% among women in the same age group.[3]

The impact of obstructive sleep apnea (OSA) and insomnia on cardiovascular disease (CVD) and metabolic disorders is striking.[4,5] Population-based studies show that individuals with OSA or insomnia are at significantly greater risk for CVD and cerebrovascular diseases (eg, arrhythmias, atherosclerosis, coronary heart disease [CHD], heart failure, hypertension, and stroke) and metabolic disorders (eg, obesity, type 2 diabetes mellitus, and dyslipidemia).[6–11] Of note, both OSA and insomnia are associated with insufficient sleep durations, which may have independent effects on these chronic diseases.[12] Below, we provide a brief description of sleep disorders and inadequate sleep duration (short sleep, defined as <7 h/night, or long sleep, defined as ≥9 h/night, unless otherwise noted) and provide evidence of the prevalence of these sleep-related problems in the general population and their effects on overall cardiometabolic health. A search of Ovid Medline, Embase, Cochrane, and clinicaltrials.gov was conducted in February 2015 with the following search terms: *sleep duration* (*sleep*, *sleep deprivation*, *sleep duration*, *sleep restriction*), *sleep*

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disorders (*sleep disorder*, *insomnia*, *obstructive sleep apnea*, *periodic limb movement disorder*, *restless leg syndrome*, *sleep disordered breathing*), *cardiovascular disease* (*cardiovascular disease*, *type 2 diabetes mellitus*, *hypertension*), *cardiometabolic risk factors* (*insulin sensitivity*, *blood pressure*, *inflammation*, *inflammatory markers*, *lipids*, *lipid profile*), *energy balance* (*body weight*, *obesity*, *overweight*, *weight loss*, *weight reduction*, *diet*, *energy intake*, *energy metabolism*, *energy balance*, *energy expenditure*, *resting metabolic rate*, *eating*, *food intake*, *leptin*, *ghrelin*), and *behavior modification* (*behavior modification*, *behavior therapy*, *conditioning therapy*, *sleep hygiene*, *sleep restriction therapy*, *cognitive behavioral therapy for insomnia*, *barriers*, *electronic devices*, *screens*, *tablets*). Our search was restricted to human subjects research published on or after 2005 in the English language.

OSA is the most prevalent sleep disordered breathing (SDB) condition, caused by a repeated narrowing of the upper airway during sleep. The most common characteristics include periods of breathing cessations, oxygen desaturations, and repetitive awakenings during sleep. Individuals with OSA often report a history of snoring, poor memory, morning headaches, and daytime sleepiness.[13] Some individuals with OSA may also experience comorbid insomnia and short sleep. It is estimated that ≈10% of men and 3% of women <50 years of age have OSA, with estimates rising to 17% and 9% for men and women ≥50 years of age, respectively.[3] Available data also suggest that OSA may be more prevalent among individuals of minority backgrounds.[14] In fact, a study comparing blacks and whites 2 to 86 years of age found that 31% of blacks had OSA compared with 10% of whites.[14]

Insomnia, which may be a manifestation of a medical or psychiatric condition, is characterized by 3 primary symptoms: difficulty falling asleep, difficulty staying asleep, and early morning awakenings that occur at least 3 nights a week for at least 3 months; some individuals also complain of feeling tired on awakening. According to a number of epidemiological studies, the prevalence of insomnia symptoms in the previous year ranges from 30% to 45%.[15] Although this condition is relatively common, only 6% of people with insomnia receive a diagnosis.[16] Of note, women and those ≥65 years of age are more likely to report insomnia symptoms, although men and women from lower socioeconomic positions and education levels also tend to complain of insomnia.[16]

Recent evidence that habitual sleep duration is a risk factor for cardiometabolic conditions has given rise to multiple epidemiological and surveillance studies. The preponderance of evidence emanating from self-reported data suggests a curvilinear relationship between habitual sleep duration and various medical conditions (eg, obesity, hypertension, and diabetes mellitus) such that both short sleep duration (SSD) and long sleep duration are associated with those conditions.[17] Published data suggest that SSD, defined in the extant literature as sleep durations <7 hours,[18] may have gradually increased over the past 40 years. Using data from the National Health Interview Survey, investigators examined trends in the prevalence of SSD, finding that it has, in fact, gradually increased, with 21.6% of US adults reporting SSD in 1977 compared with 29.1% in 2009.[19] Notably, these prevalence estimates were comparable to estimates derived from the Sleep Heart Health Study.[20] Indeed, available data suggest that 27.5% of American adults reported SSD in 2005.[21]

In terms of long sleep, defined as sleep durations ≥9 hours, data suggest that its prevalence may have decreased from 11.6% reported in 1977 to 7.8% in 2009.[19] This reduction in the prevalence of long sleep duration could simply be a reflection of the gradual decline in overall sleep duration, as has been demonstrated in other published studies. Examination of data gathered from 1959 to 2005 revealed a decrease in modal sleep durations of ≈1.5 hours.[22] On balance, a recent systematic review suggested that long sleep may be a greater concern than SSD,[23] although experimental findings strongly indicate that SSD, rather than long sleep, is associated with adverse physiological and immunological consequences.[24–27] Self-reported sleep durations may be affected by various factors, including demographic profiles, family structure, socioeconomic position, employment status, health risk behavior, and general health status.[28] The lack of objective measures of sleep duration in the majority of large-scale epidemiological studies is certainly a limitation that we wish to acknowledge at the forefront of this review. Nonetheless, despite the potential confounders introduced by the use of self-reports, these studies provide a valuable framework that warrants additional investigation using objective measures of sleep.

In this report, we review the epidemiological and clinical evidence relating sleep duration and some sleep disorders (insomnia/insomnia symptoms, SDB, periodic limb movement disorder, restless leg syndrome) to major risk factors for CVD such as obesity, type 2 diabetes mellitus, and hypertension, as well as CVD.

SLEEP DURATION AND OBESITY RISK

Epidemiological Evidence

Many epidemiological studies have described associations between self-reported habitual SSD and obesity. A meta-analysis by Cappuccio and colleagues[29] found that across 23 studies of adults, a pooled odds ratio of 1.55 was found. Furthermore, analysis of 7 studies that examined linear relationships between sleep duration and body mass index as a continuous variable showed that for every increased hour of sleep, body mass index was reduced by 0.35 points.[29] These findings are echoed in

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several qualitative reviews on this topic,[30–38] which all agree that individuals with habitual SSD are more likely to be obese than those with normal sleep habits (generally 7–8 hours of sleep a night).

Among these cross-sectional studies, several have identified important moderators of effects. For example, analyses of nationally representative data collected as part of the 2009 Behavioral Risk Factor Surveillance System made 2 notable findings on the sleep-obesity relationship. First, this analysis found that although the majority of individuals with SSD slept in the 5- to 6-hour range, the most pronounced effects were seen among those reporting ≤4 hours of sleep per night.[39] This finding suggested that risk varied across sleep duration; very short sleep (which more closely resembled sleep duration achieved in acute sleep restriction studies) seemed to carry greater risk than more typical short sleep. The second important finding in this study was that the relationship to obesity was independent of self-reported perceived sleep insufficiency.[39] A pair of notable studies that analyzed data from the 2007 to 2008 NHANES (National Health and Nutrition Evaluation Survey) found that the relation between sleep duration and obesity depends on age[40] and race/ethnicity.[41] Specifically, the relation between SSD and obesity is stronger among younger than among older adults.[40] This finding is consistent with many studies that show that sleep loss in children and adolescents is a consistent risk factor for obesity in those groups.[42] Furthermore, the relationship between SSD and obesity varies among blacks and whites,[41] with blacks in the United States being disproportionately affected by SSD with respect to obesity risk.[43]

Although cross-sectional studies often have the benefit of increased sample size and statistical power, it is impossible to determine the direction of effects. Further complicating this is the wording of survey items, which tends to focus on recent habitual sleep duration relative to obesity, which presumably developed over a much longer period. Thus, studies of incident weight gain and obesity are particularly helpful in this regard. Several key studies have identified habitual SSD as a risk factor for incident weight gain and obesity. In a landmark analysis of data from the Nurses' Health Study, women sleeping ≤5 hours a night on average gained 1.14 kg more weight over 16 years and women sleeping 6 hours gained 0.71 kg more weight compared with women sleeping at least 7 hours.[44] Furthermore, those sleeping ≤5 or 6 hours were 32% and 12% more likely to gain 15 kg over the 16-year follow-up period, respectively. These findings were replicated and extended with data from the Québec Family Study showing that over the course of 6 years, habitual short sleepers were more likely to gain weight and to have increased waist circumference and percent body fat compared with normal-duration sleepers. Notably, there was a U-shaped relationship in which a similar pattern was seen for habitual long sleepers.[45] In a study of male Japanese workers,[46] habitual sleep duration of <6 hours was associated with increased likelihood of developing obesity over the course of 1 year. Taken together, these and other studies suggest that habitual SSD leads to weight gain and obesity over time.

Several possible reasons for this exist. As described below, habitual SSD may lead to metabolic changes and cardiometabolic risk factors. In addition, SSD could lead to neurocognitive changes that could result in weight gain, including impaired judgment and decision making, which could presumably alter food choice,[47] and fatigue and tiredness, which could result in decreased physical activity. Additionally, sleep loss may lead to increased food intake despite little change in energy expenditure, leading to a positive energy balance.[48]

An emerging evidence base suggests that SSD is related to food intake. Among factory workers in Japan, SSD was associated with more snacking between meals, more irregular eating habits, less consumption of vegetables, and a greater preference for strongly flavored food.[49] In the United States, a study of 459 postmenopausal women enrolled in the Women's Health Initiative examined relationships between dietary records and sleep diary and actigraphy variables.[50] This study showed that SSD, measured objectively with actigraphy, was strongly associated with higher intakes of many dietary fat–related variables.

From nationally representative data, analysis of the 2007 to 2008 NHANES showed that self-reported long sleepers consumed fewer calories than 7- to 8-hour sleepers.[51] Additionally, very short (<5 hours), short (5–6 hours), and long sleepers consumed a smaller variety of foods (fewer number of foods consumed on the measurement day) compared with 7- to 8-hour sleepers. In an examination of nutrient profiles, very short sleep and long sleep were associated with lower consumption of protein, carbohydrate, fiber, and fat relative to 7- to 8-hour sleep (long sleepers consumed less sugar, and short sleepers consumed less fiber). These observations were made after adjustment for other dietary intake variables, including total caloric intake.[51] Data thus suggest that SSD is associated with poor dietary quality.

Epidemiological data linking sleep duration with energy expenditure are relatively scarce. The reason may be that the relationship between sleep and energy expenditure is complex. For example, analysis of >300 000 respondents to the 2009 Behavioral Risk Factor Surveillance System showed that self-reported perceived sleep insufficiency was associated with self-reported physical activity variables but that this relationship was generally nonlinear. Moderate exercise was generally not associated with insufficient sleep for values up to ≈1 h/d, and vigorous physical activity was nonlinearly but generally associated with greater insufficient sleep, which was consistent with employment data showing that manual labor was associated with more insufficient sleep than

jobs that included mostly sitting or standing. In contrast, however, those engaging in no activity reported more insufficient sleep than those engaging in some activity.[52]

This finding is consistent with data from a previous wave of the Behavioral Risk Factor Surveillance System that found that those individuals who reported any exercise in the past 30 days (regardless of amount) were about a third less likely to report sleep disturbances and about half as likely to report daytime tiredness.[53] This is consistent with data from the National Sleep Foundation that found that increased sedentary time was associated with poorer sleep quality.[54] Also consistent with the data on insufficient sleep, there was no relationship between sedentary time and sleep duration. It may even be the case that shorter sleepers get more exercise on average. In data from the 2007 to 2008 NHANES, minutes of moderate and vigorous exercise differed across sleep duration groups; the shortest sleepers reported the most exercise, and the longest sleepers reported the least.[51]

The relationships between sleep and energy expenditure are clearly complex and may not be well measured at the population level. For example, there may be subgroups of short sleepers who, by virtue of having more wake time, are more physically active, whereas others who sleep poorly have less energy and ability to be active. It seems to be the case, however, that decreased physical activity plays a role in the relation between sleep and CVD. In an analysis of data from the National Institutes of Health–AARP Diet and Health Study, SSD predicted CVD mortality, especially among overweight and obese people, and the combination of SSD, low physical activity, and overweight status was associated with an increased likelihood of all-cause, cardiovascular, and cancer-related mortality.[55]

Epidemiological evidence thus clearly describes a relation between SSD and increased energy intakes. Much less clear is the relation between sleep duration and physical activity level. Given the association between SSD and obesity, however, the preponderance of evidence suggests a mismatch between energy intake and energy expenditure favoring a positive energy balance. This is assessed in clinical intervention studies.

Clinical Evidence

Impact of Sleep Restriction on Energy Intake

Several studies have assessed energy intake after periods of sleep restriction, usually 4 hours in bed, relative to periods of habitual sleep, usually 8 to 10 hours in bed.[56–64] With 2 exceptions,[57,60] studies have generally been performed in normal-weight individuals. In general, studies reported increases in 24-hour energy intake when participants underwent sleep restriction relative to habitual sleep (Table 1), with the degree of overeating ranging from ≈180 to 559 kcal/d. Few studies also reported no difference in energy intake[56,63,64] between sleep conditions. One of those studies was a small study with young men and women randomized to either sleep restriction or habitual sleep that found a significant increase in food intake with sleep restriction relative to baseline but no between-group difference.[56] The other 2 studies were performed exclusively in young, healthy men.[63,64] One study reported greater hunger ratings but no difference in intake at a single late-afternoon buffet meal after a period of sleep restriction.[63] The other study reported greater fat intake but not total energy intake after sleep restriction.[64]

Several mechanisms have been posited to explain the greater energy intake observed after periods of sleep restriction. Studies have reported alterations in appetite-regulating hormones, particularly leptin and ghrelin but also glucagon-like peptide 1 in women. However, data in this area are mixed,[34] with studies showing increased,[57,59,65–68] reduced,[69,70] or no difference in [56,63,64,71,72] leptin levels with sleep restriction. Similarly, ghrelin levels have been reported to be increased[69,70,72–74] or not different[56,60,64,71] with sleep restriction relative to habitual sleep. Only 1 study reported glucagon-like peptide 1,[72] showing reduced levels with sleep restriction relative to habitual sleep in women but not in men. Neuroimaging studies have highlighted a role of the neuronal reward network in response to foods as an attempt to explain enhanced food intake after periods of sleep restriction.[75–77] Conclusions from those studies are in line with data showing that participants select larger portion sizes, even in the sated state,[74] and report greater food purchases[78] in mock portion size and supermarket tasks, respectively, after a night of total sleep deprivation relative to an 8-hour sleep opportunity.

Impact of Sleep Restriction on Energy Expenditure

On the flip side of the energy balance equation, data on the effects of sleep duration on energy expenditure are also mixed.[34] This is due in part to the multicomponent nature of energy expenditure: total energy expenditure, resting metabolic rate, sleeping metabolic rate, physical activity energy expenditure, and diet-induced thermogenesis, as well as the multiple ways by which energy expenditure can be assessed: actigraphy/accelerometry, indirect calorimetry, metabolic chamber, and doubly labeled water. Studies that have examined the impact of sleep duration on resting metabolic rate using indirect calorimetry have found either no difference[57,62,79–81] or a lower resting metabolic rate[69] with sleep restriction relative to habitual sleep. As part of a weight loss diet, sleep restriction leads to greater reduction in resting metabolic rate than habitual sleep.[73]

When 24-hour energy expenditure was measured by doubly labeled water, no difference between sleep restriction relative to habitual sleep was observed.[60,75]

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Table 1. Impact of Sleep Restriction on Food Intake

Study	Participants	Sleep Intervention	Outcome (Sleep Restriction)
Benedict et al,[63] 2011	14 Men	24 h with 8 h TIB or TSD	Greater morning hunger
	Normal weight		No difference in energy intake at afternoon buffet
	Mean age, 23 y		
Bosy-Westphal et al,[57] 2008	14 Women	2 Nights of >8 h TIB followed by consecutive nights of 7, 6, 5, and 4 h TIB	Energy intake was increased by 415 kcal/d relative to baseline
	8 Normal weight, 3 overweight, 3 obese		
	Mean age, 27.5 y		
Brondel et al,[58] 2010	12 Men	48 h with 8 or 4 h TIB	Energy intake was increased by 559 kcal/d
	Normal weight		
	Mean age, 22 y		
Calvin et al,[56] 2013*	11 Men, 6 women	Reduce sleep to 2/3 habitual sleep or maintain habitual sleep, 8 d	Energy intake was increased by 559 kcal/d relative to baseline
	Normal weight		
	Mean age, ≈25 y		
Markwald et al,[59] 2013	8 Men, 8 women	5 d of 5 or 9 h TIB	Energy intake was increased by 6% (182 kcal/d)
	Normal weight		
	Mean age, 22.4 y		
Nedeltcheva et al,[60] 2009	6 Men, 5 women	14 d of 5.5 h or 8.5 h TIB	Total energy intake was increased by 297 kcal/d (NS); snack intake was increased by 221 kcal/d
	Overweight		
	Mean age, 39 y		
Schmid et al,[64] 2009	15 Men	2 d with 4 or 8 h TIB	Energy intake was similar, but fat intake was increased
	Normal weight		
	Mean age, 27 y		
Spaeth et al,[61] 2013*	Sleep restriction: 15 men, 16 women	Sleep restriction: 1 baseline night (8 h TIB) followed by 4 nights of 4 h TIB and 2 nights of 10 h TIB	Energy intake was increased by ≈511 kcal/d when bedtime was delayed and sleep restricted to 4 h TIB
	Control: 4 men, 2 women	Control, 10 h TIB	
	Normal weight to overweight		
	Mean age, ≈34 y		
St-Onge et al,[62] 2011	13 Men, 13 women	5 Nights of 4 h TIB or 9 h TIB	Energy intake was increased by 296 kcal/d
	Normal weight		
	Mean age, ≈35 y		

NS indicates not significant; TIB, time in bed; and TSD, total sleep deprivation.
*Parallel-arm study.

However, when 24-hour energy expenditure was measured in a metabolic chamber, which provides a more confined environment, energy expenditure was increased with sleep restriction relative to habitual sleep.[59,82,83] The increase in energy expenditure associated with sleep restriction could be accounted for by the added cost of maintaining wakefulness.

Finally, free-living physical activity assessed by accelerometry seems to be minimally altered. Some have reported lower high-intensity activity and higher low-intensity activity with sleep restriction,[62,64] whereas others[56,57] have found no difference in physical activity energy expenditure. On the other hand, when sleep duration was reduced as a result of sleep fragmentation, physical activity was increased.[71] Such observations were also made in a crossover sleep restriction study, but the difference between sleep conditions was estimated to be an ≈48-kcal greater expenditure with sleep restriction.[58] Nonetheless, differences in energy expenditure with sleep restriction do not appear to be sufficient to counter the increase in energy intake reported above.

Data therefore do not support a fundamental alteration in energy metabolism as a result of SSD. In fact, as a result of added time awake, resting energy expenditure is increased when sleep is restricted. However,

clinical intervention studies have not provided sufficient information to conclude on the impact of sleep restriction on physical activity level. This area of research should be expanded.

Impact of Sleep Restriction on Body Weight

Studies that have assessed the impact of sleep restriction on change in body weight in the context of ad libitum feeding have mostly been small, short-term studies.[57,59–61,73,84] One study[57] showed an increase of 0.4 kg in body weight in women as sleep was progressively restricted from >8 h/night at baseline to 4 h/night over 4 nights, and another study[59] found weight gain over a 5-night period of 5 hours in bed relative to 9 hours in normal-weight men and women in a crossover study. In a 2-arm study, individuals undergoing sleep restriction to 4 h/night for 5 nights gained more weight than those provided an 8-hour sleep opportunity, with the weight gain being greater in men than women and in blacks compared with whites.[61] Longer-term studies, however, have not found an impact of sleep restriction on body weight. There was no difference in change in body weight assessed by dual energy x-ray absorptiometry when participants were provided a 5.5-hour sleep opportunity relative to 8.5 hours for 14 days as inpatients,[60] nor was body weight different from baseline after 3 weeks of a 1.5-hour sleep restriction relative to habitual sleep in an outpatient study conducted exclusively in men.[84] In the latter study, however, there was a significant treatment-by-week interaction such that weight was initially reduced in the sleep restriction group and rose back to baseline between weeks 2 and 3. It is unknown whether body weight would have continued in an upward trajectory had the study been prolonged beyond 3 weeks. Studies are needed to evaluate the longer-term impact of sleep restriction on energy balance with weight status and body composition as the outcome variables.

One study was conducted as a controlled-feeding weight loss study in which participants concurrently underwent sleep restriction or habitual sleep for 14 days in a crossover design.[73] Because of the controlled-feeding nature of the study, participants lost an equivalent amount of weight in both sleep conditions. However, in the sleep restriction condition, participants lost more fat-free mass and less fat mass than when the same weight loss treatment was performed with an 8-hour sleep opportunity. Whether similar results are observed in the context of weight gain remains to be determined.

Overall, there is good agreement that sleep restriction increases energy intake, and evidence shows that this is not accompanied by an adequate compensation via increased energy expenditure. Although data are mixed and somewhat inconclusive in terms of the impact of sleep restriction on energy expenditure, the net result seems to be positive energy balance, with studies showing a strong impact of sleep restriction on increased food intake, particularly from fat and snacks,[60,62,64] at least in the short term. Studies are needed to assess the longer-term impact of sleep restriction on energy balance with changes in body composition as the main outcome variable to truly determine whether SSD is a causal factor in the development of obesity. Studies should also include more women, older adults, and overweight or obese individuals, all of whom have been underrepresented in studies to date.

SLEEP DURATION, CARDIOMETABOLIC RISK, AND CLINICAL END POINTS

Epidemiological Findings

Epidemiological research has reported the association between sleep duration, quality, and cardiometabolic risk. These topics have been the subject of several meta-analyses, which are described below and summarized in Table 2. In fact, emerging cross-sectional data have shown that SSD is consistently associated with metabolic syndrome (a constellation of symptoms, including elevated waist circumference, lipids, fasting glucose, and blood pressure). Specifically, SSD is positively associated with the odds or risk of developing the metabolic syndrome,[85–91] with similar metabolic effects being shown in individuals with long sleep duration.[85,87]

Diabetes Mellitus

Two recent meta-analyses on the association between SSD and development of diabetes mellitus have been published.[92,93] The findings were similar, showing an ≈30% increased risk. The first, based on 7 studies, showed a relative risk (RR) of 1.28 (95% confidence interval [CI], 1.03–1.60) with evidence of heterogeneity; there was a significant effect in men but not women.[92] The second meta-analysis, based on 10 studies, showed an odds ratio of 1.33 (95% CI, 1.20–1.48) without evidence of

Table 2. Associations Between Sleep Duration and Disorders and Incident CVD: Summary of Recent Meta-Analyses

Disorder	Short Sleep	Long Sleep	Insomnia	SDB
Diabetes mellitus	+	+	+	+
Hypertension	+	X	NA	NA
CHD	+	+	NA	X
Stroke	+	+	NA	+
Total CVD	X	+	+	+

CHD indicates coronary heart disease; CVD, cardiovascular disease; NA, no recently reported meta-analysis identified; SDB, sleep-disordered breathing; +, statistically significant positive relationship; and X, no statistically significant relationship.

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heterogeneity.[93] Only 1 meta-analysis, based on 6 studies, found an association between long sleep duration and development of diabetes mellitus (RR=1.48; 95% CI, 1.13–1.96) without statistically significant heterogeneity.[92] Potential confounders were variably adjusted for in the original studies included in these meta-analyses.[89,90] The minority of studies included adjustment for snoring, but none adjusted for SDB.

Hypertension

The association between SSD and hypertension has also been well studied in 3 recent meta-analyses. Two showed similar results without evidence of heterogeneity (RR=1.21; 95% CI, 1.05–1.40 based on 6 studies[94]; and RR=1.23; 95% CI, 1.06–1.42 based on 5 studies[95]). However, the other meta-analysis, based on 6 studies, did not find an association between SSD and the risk of incident hypertension (RR=1.11; 95% CI, 0.84–1.47) with evidence of heterogeneity across studies.[96] The risk was increased among those <65 years of age but was not increased in those ≥65 years of age without heterogeneity within each sex subgroup.[96] Potential confounders were variably adjusted for in the original studies included in these meta-analyses.[91–93] Unaccounted-for variables such as SDB could represent potential confounders of the SSD-hypertension association. Despite associations between long sleep duration and prevalent hypertension,[96] 3 meta-analyses, each based on 5 studies, have been reported recently, and none found an association between long sleep duration and the development of hypertension.[94–96] Of note, whereas associations of SSD and some cardiometabolic risk factors are typically significant in young but not older adults, no difference was found between age groups <65 or >65 years of age in the association between long sleep and hypertension.[96]

Cardiovascular Disease

A meta-analysis based on 7 studies demonstrated an increased risk of developing or dying of CHD associated with both SSD (RR=1.48; 95% CI, 1.22–1.80) and long sleep duration (RR=1.38; 95% CI, 1.15–1.66) with some heterogeneity.[97] Sex, geographical area, and duration of follow-up were explored as potential causes of heterogeneity, but none contributed to this effect. Sleep-inducing medications, perhaps used more frequently in those with SSD, could modify the effect of SSD on CHD or serve as a potential confounder of the SSD-CHD association but were not explored in these meta-analyses. In a separate study,[98] SSD and CHD mortality were associated among those who used tranquilizers or hypnotics regularly or rarely but not in those who never used them, supporting the possibility of effect modification.

A meta-analysis based on 4 studies identified a modest association between SSD and incident stroke (RR=1.15; 95% CI, 1.00–1.31) with no heterogeneity across studies.[97] In this meta-analysis, there was also an association between long sleep duration and stroke (RR=1.65; 95% CI. 1.45–1.87) with no heterogeneity across studies.[97]

A meta-analysis found no association between SSD and total CVD (including any CVD-related cause of death) despite associations with CHD and stroke with no heterogeneity across studies.[97] There was, however, an association between long sleep duration and the combination of incident CVD and CVD mortality (RR=1.41; 95% CI, 1.19–1.68) with heterogeneity across studies that was not attributable to sex, follow-up duration, or geographical location. Of note, a recent study not included in this meta-analysis showed a significant association between SSD, but not long sleep duration, and CVD in less healthy individuals (hazard ratio [HR]=1.38; 95% CI, 1.12–1.70), defined as having a serious illness at baseline or Medical Outcomes Study Physical Functioning score <75.[93] There was no association in healthy individuals (HR=0.92; 95% CI, 0.75–1.14).

Impact of Sleep Restriction on Cardiometabolic Risk Factors

Insulin Resistance

Sleep restriction contributes to and is associated with a variety of adverse metabolic outcomes. Experimental sleep restriction in healthy adults results in increases in insulin resistance[99] and decreases in insulin sensitivity.[81] SSD is associated with increases in fasting insulin and hemoglobin A_{1c}, which may be mediated by body mass index.[100] Sleep restriction is associated with a 3-fold increase in the odds of having impaired fasting glucose,[26] which may be driven by insulin resistance.[26,84] Under controlled laboratory conditions, consecutive daily sleep restriction of ≈2 hours results in increased insulin resistance and decreased glucose tolerance in response to a glucose challenge.[101]

Cardiovascular and Proinflammatory Markers

Researchers have examined the effect of sleep restriction on blood pressure outcomes (systolic, diastolic, and nocturnal blood pressure dipping, a disturbance in the normal circadian blood pressure pattern). In a crossover trial, healthy younger and older adults were randomized to either 24 hours including habitual sleep or 24 hours of total sleep deprivation. Normotensive older adults experienced a 13–mm Hg increase in systolic blood pressure and a 7–mm Hg increase in diastolic blood pressure after sleep deprivation compared with habitual sleep.[102] Nocturnal blood pressure dipping also decreases after restricted sleep (<6.5 hours),[103,104] which may further increase CVD risk.

Sleep restriction has been shown to affect a variety of other cardiovascular markers. In a randomized, crossover trial of younger healthy adult men, 5 nights of restricted sleep (<5 hours) in a laboratory setting resulted in an increase in sympathetic nervous system activity

(increased low-frequency heart rate variability and decrease in high-frequency heart rate variability), an increase in serum norepinephrine, and a decrease in maximum endothelium-dependent venodilation compared with 5 nights of habitual sleep of >7 hours.[105] Similarly, 40 hours of total sleep deprivation under controlled laboratory conditions resulted in increases in proinflammatory markers (intercellular adhesion molecule-1, e-selectin, interleukin-1β, interleukin-6, C-reactive protein) and a decrease in interleukin-1 receptor antagonist (an anti-inflammatory marker).[106] Relatedly, healthy adults subjected to restricted sleep (4 hours of time in bed) over 5 consecutive nights experienced an increase in proinflammatory cytokines (interleukin-6, interleukin-1β, interleukin-17, mRNA) compared with those who underwent 8 hours of habitual time in bed.[107] Finally, in a randomized, crossover trial, young normal-weight adults who underwent 5 nights of SSD (<4 hours) or 5 nights of habitual sleep (>9 hours) showed no significant differences in lipid profile between sleep conditions.

SLEEP DISORDERS AND CARDIOMETABOLIC RISK

Epidemiological Findings

Diabetes Mellitus

No meta-analysis was available to assess the relation between insomnia and type 2 diabetes mellitus. However, a meta-analysis based on 5 studies corroborated an association between insomnia symptoms such as difficulty initiating sleep and the development of diabetes mellitus (RR=1.57; 95% CI, 1.25–1.97) and difficulty maintaining sleep and incident diabetes mellitus (RR=1.84; 95% CI, 1.39–2.43).[92] No heterogeneity was noted across studies.

A meta-analysis based on 6 studies addressed the association between SDB and diabetes mellitus.[108] This analysis found that moderate to severe SDB (apnea/hypopnea index [AHI] ≥15) was associated with a greater risk of the development of diabetes mellitus compared with the absence of SDB. Data from 3 studies of individuals with mild SDB compared with those without SDB showed that there was no association with the development of diabetes mellitus (RR=1.22; 95% CI, 0.91–1.63).

Hypertension

Studies that have investigated the association between insomnia symptoms and the development of hypertension have shown mixed or nuanced results. Based on subjective symptoms only, a modest association between combined insomnia symptoms (RR=1.05; 95% CI, 1.01–1.08)[94] or some combination of symptoms such as difficulty falling asleep or waking up repeatedly and the development of hypertension has been found.[109] Although another study in a relatively healthy older cohort showed that insomnia symptoms were protective against the development of hypertension in adjusted models only in men who were not black, no association was identified in women or blacks.[110] The association of sleep disturbance symptoms is complicated by an interaction with objective measures of sleep duration. For instance, chronic insomnia with ≥6 hours of objective sleep was not associated with the development of hypertension, whereas those symptoms, in combination with SSD, were associated with the development of hypertension when adjusted for potential confounders.[111] Another study found that insomnia was associated with the development of hypertension after adjustment for sleep duration in individuals 32 to 59 years of age but not in those 60 to 86 years of age.[112]

A previous American Heart Association scientific statement reviewed the evidence in support of a relation between SDB and hypertension, referring to SDB as an identifiable cause of hypertension.[113] Longitudinal studies since that time have confirmed an association between severe SDB (AHI ≥30) and new-onset hypertension in the elderly[114] but did not show an association between objectively measured SDB and incident hypertension in middle-aged adults after adjustment.[115] Furthermore, the Sleep Heart Health Study demonstrated an association between an AHI ≥30 and the development of hypertension, but this association was no longer significant after adjustment for body mass index. Associations were present after adjustment in women and those with a body mass index ≤27.3 kg/m^2.[116]

Cardiovascular Disease

Studies that have investigated the association between insomnia symptoms and CHD have generally found an association, although sex differences may exist. Restless, disturbed nights (a combination of response options of "rather more than usual" and "much more than usual") have been found to be associated with CHD after adjustment for confounders.[117] After adjustment for potential confounders, including depression and anxiety, difficulty initiating sleep almost every night, difficulty maintaining sleep almost every night, and a feeling of nonrestorative sleep more than once a week were associated with acute myocardial infarction (MI) compared with never experiencing these sleep difficulties.[118] In this study, the number of insomnia symptoms was associated with MI risk in a dose-dependent fashion.[118] The relationship between insomnia symptoms and MI appeared to be stronger in women than men.[118] In another study with full adjustment, incident MI was associated with difficulty maintaining sleep in women but not men. Difficulty initiating sleep was not significantly associated with CHD in women or men.[119] Additionally, in an all-male study, frequent insomnia was no longer significantly associated with CHD after adjustment for potential confounders.[120]

Few studies have addressed the association between insomnia and incident stroke, but in general, the results

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have supported an association. In an all-male prospective cohort study, frequent insomnia was associated with incident stroke after adjustment for potential confounders.[120] Similarly, in a study of working-aged adults, insomnia symptoms were associated with self-reported stroke after adjustment for demographics, anxiety, and depression.[121] Finally, a retrospective cohort study found that insomnia was associated with hospitalization for stroke on the basis of diagnosis codes.[122]

A meta-analysis based on 13 studies corroborated the association between insomnia symptoms and developing or dying of CVD (RR, 1.45; 95% CI, 1.29–1.62).[123] However, 1 study identified an association between insomnia symptoms and CVD only in those with both SSD and poor-quality sleep.[124]

SDB is a group of sleep pathologies that include OSA and is characterized by abnormal respiratory patterns during sleep. Although SDB, detected by polysomnography, has been linked to the development of CHD, the association does not appear to be statistically significant.[125] Three meta-analyses, each with evidence of at least moderate heterogeneity, showed nonsignificant associations.[125–127] A cohort study in women published only since the meta-analyses supported the nonsignificant association between untreated SDB and the development of CHD compared with no SDB (AHI <10).[128]

In a meta-analysis, studies using both clinical populations referred for polysomnography because of suspicion of SDB and community-based samples have shown an association between SDB and the development of ischemic stroke.[129] The overall association was an RR of 2.10 (95% CI, 1.50–2.93) in 10 studies.[129] Other meta-analyses have shown a similar association between severe SDB and stroke.[125,126] It has been noted that better evidence exists in men.[125] In the single study available in women only, the association was not significant.[125] However, since these meta-analyses were published, a prospective cohort study performed in women found a clear association between SDB and incident stroke (HR=6.44; 95% CI, 1.46–28.3).[128]

For the combined outcome of CVD, moderate and severe SDB, but not mild SDB, was shown to be associated with an elevated risk.[126] The pooled RR of CVD per 10-unit increase in AHI was 1.17 on the basis of 6 prospective cohort studies.

Another sleep disorder, restless leg syndrome, has been investigated as a CVD risk factor. Although findings from prospective cohort studies have been mixed with respect to the association between restless leg syndrome and the development of CVD, the majority of the studies have been negative. No association between restless leg syndrome and stroke, MI, or major cardiovascular events was found in age-adjusted or multivariable-adjusted analyses from 2 large, single-sex, prospective cohort studies of health professionals, the Physicians Health Study and the Women's Health Study.[130] In an all-male study, the symptom of restless legs was not associated with CHD after adjustment for potential confounders.[120] In the Nurses' Health Study, longer duration of restless leg syndrome diagnosis (>3 years) was associated with CHD and nonfatal MI in adjusted models in women.[131] The diagnosis of restless leg syndrome for <3 years at baseline was not associated with the development of CHD or MI.[131] In an all-male study, the symptom of restless legs (restless legs or bothersome twitches once or twice a week or more) was associated with the development of stroke[120] after adjustment for potential confounders. In those with end-stage renal disease on hemodialysis, a population with a high prevalence of restless legs, neither continuous restless leg syndrome symptoms nor intermittent symptoms were associated with the development of a new CVD event in adjusted models.[132]

A retrospective cohort study using administrative data showed that among those who had a polysomnogram for suspected SDB, the number of periodic leg movements per hour (13.4 vs 0) was associated with composite CVD events but not with MI or stroke.[133] For CHD, an association was identified for a periodic limb movement index ≥30 in an unadjusted model (HR=1.38; 95% CI, 1.07–1.79) but not when adjusted for confounders (HR=1.26; 95% CI, 0.97–1.65). For cerebrovascular events, no association was found in unadjusted or adjusted analyses, although there were few events and thus limited power.[134] In addition, despite an association between periodic limb movement index and prevalent hypertension, an association was not found with incident hypertension among community-dwelling elderly men.[134]

Preliminary data suggest that sleep extension may have the potential to improve cardiovascular risk factors.[135] In a small pilot study, 22 subjects with prehypertension or stage 1 hypertension and sleep durations of ≤7 hours were randomized to sleep extension or maintenance groups, with a goal of increasing sleep duration by 1 hour over 6 weeks. Although there was a reduction in blood pressure in both groups, it was greater in the group randomized to sleep extension (although the difference between groups was not statistically significant). Larger studies will be necessary to evaluate this approach more rigorously. Similarly, small studies suggest that there may be an effect of treating insomnia by behavioral interventions in reducing the levels of the inflammatory marker C-reactive protein.[136] Again, larger, more rigorous trials with cardiovascular end points will be necessary to make these findings clinically relevant.

LIFESTYLE INTERVENTIONS FOR SLEEP DISORDERS

Impact of Weight Loss on Sleep Disorders

The results of 4 randomized, controlled trials have shown that weight loss achieved through behavioral or surgical interventions may be effective in the man-

agement or resolution of SDB (measured by change in AHI).[137–140] In 1 trial, researchers found that a 20-kg (95% CI, 18–21) weight loss achieved by a very-low-calorie diet resulted in a significant reduction in AHI at 9 weeks (−25±17 events/h) compared with usual diet controls (−2±11 events/h).[139] In a prospective observational follow-up of the same trial participants during a weight maintenance period, significant improvements in AHI were maintained at 52 weeks (−17 events/hour; 95% CI, −13 to −21 events/h) compared with baseline.[139] Ten percent of those in the intervention group achieved complete resolution of OSA at 12 months, with 48% no longer requiring continuous positive airway pressure (CPAP). Furthermore, individuals with severe OSA (AHI >30 events/h) achieved greater reductions in AHI after weight loss (−38 events/h) compared with those with moderate OSA (−12 events/h).[139] Results of another trial (ancillary to the LookAhead trial) found that intensive lifestyle intervention produced a significantly greater reduction in AHI (−9.7±2, −8±2, and −7.7 ± 2.3 events/h at 12, 24, and 48 months, respectively), with complete resolution of OSA being 5 times more likely in the intervention group compared with the control group.[137] In another trial, individuals with mild OSA (AHI=5–15 events/h) received 12 weeks of a very-low-calorie diet plus lifestyle counseling (n=26) or lifestyle counseling alone (n=26).[140] Although these researchers found a 5.4-kg/m^2 difference in body mass index between the intervention and control groups at follow-up, no significant difference was shown in AHI or associated nasal resistance. Notably, these authors did not report attrition rates or whether intent-to-treat analyses were performed, which limits the interpretation of these findings. Lastly, in a comparative-effectiveness trial, obese adults with moderate OSA (AHI=17±21 events/h) randomized to lifestyle intervention or roux-en-y gastric bypass surgery lost 8% and 30 % of baseline weight respectively, at 12 months. Significant reductions in AHI were also observed, with larger reductions achieved after roux-en-y gastric bypass.[138] However, baseline body mass index was lower in the surgery group compared with the lifestyle group, and only 63% of participants had OSA (AHI >5 events/h) at baseline, which limits the conclusions that can be drawn.

In a series of observational cohort studies, weight loss has also shown promise for the resolution or improvement in SDB. Behavioral weight loss interventions[141] supplemented with subutramine[142] have resulted in significant reductions in both weight and AHI after 12 weeks[141] and 24 weeks[142] of intervention. In contrast, a 16-week intensive lifestyle intervention supplemented with low-calorie meal replacements did not result in significant improvements in AHI for obese adults with moderate OSA (AHI=24±12 events/h).[143] In the population of obese adults with OSA who have undergone bariatric surgery, researchers have evaluated the effects of a variety of procedures, including the laparoscopic adjustable gastric band, roux-en-y gastric bypass, vertical sleeve gastrectomy, or intragastric balloon. Laparoscopic adjustable gastric band has resulted in the resolution of OSA in 60%[144] and 83%[145] of cases, with others reporting 100% of cases discontinuing the use of CPAP[146] and others reporting clinically significant improvements in AHI.[147–150] Roux-en-y gastric bypass has resulted in the resolution of OSA in 75%[151] and 92%[145] of cases, with significant improvements in AHI similarly being achieved.[145,149,151–154] Vertical sleeve gastrectomy has resulted in the resolution of OSA in 92%,[145] 76%,[155] and 52%[156] of cases, with others reporting clinically significant improvements in AHI.[148,149] Lastly, in a cohort of men who received the intragastric balloon, a significant improvement in AHI was reported: 52 events/h at baseline versus 12 events/h after 6 months.[157] Although several of these studies have reported improvements in SDB after weight loss, some did not report the observed changes in AHI.[144–146,148,150,151,156,158]

Together, this emerging body of literature suggests that weight loss achieved through behavioral or surgical interventions may be effective for improving and in some cases resolving SDB. The findings from behavioral interventions are supported by 2 recent meta-analyses.[159,160] This finding may be particularly true for those with severe OSA. However, well-designed and -executed comparative-effectiveness trials are needed that will further explore the underlying mechanisms between weight loss and SDB and are transparent in the reporting of objectively measured SDB outcomes (ie, changes from baseline to posttreatment follow-up in AHI).

Impact of Treatment of Sleep Disorders on Cardiometabolic Risk Factors

Although observational studies have found an association between the treatment of sleep disorders and an improvement in cardiometabolic risk factors, primarily hypertension,[161–164] the randomized data are still rather limited. The HeartBEAT study (Heart Biomarker Evaluation in Apnea Treatment) was a randomized trial of 318 patients at 4 academic sites that assessed the effects of CPAP versus nocturnal supplemental oxygen versus usual care on cardiovascular risk factors in patients who had CVD or multiple cardiac risk factors who were found to have OSA.[165] Patients in cardiovascular practices were screened for sleep apnea with the Berlin questionnaire,[166] and those with an AHI of 15 to 50 events/h were randomized. Patients with severe sleep apnea were excluded. The primary end point of 24-hour mean arterial pressure at 12 weeks was significantly reduced in the CPAP group compared with the control group (−2.4 mm Hg) or the supplemental oxygen group (−2.8 mm Hg). However, there was no significant reduction in the supplemental oxygen group compared with

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the control group. Of note, the nocturnal systolic blood pressure was significantly reduced for each additional hour of CPAP use (–0.93 mm Hg/h). Furthermore, the odds of nondipping nocturnal blood pressure were reduced for each additional hour of CPAP use. Interestingly, compared with the control arm, CPAP use was associated with a lower adjusted level of C-reactive protein. There was no difference between CPAP treatment and supplemental oxygen groups in C-reactive protein levels at 12 weeks.

The results of HeartBEAT show the potential value of screening for sleep apnea in patients at elevated cardiovascular risk, including those whose cardiovascular risk factors are otherwise well treated.[165] In this setting, identification and treatment of OSA with CPAP reduce blood pressure by an amount that would be expected to translate into a reduction in cardiovascular events in a large enough population followed up for sufficient time. Additional analyses from HeartBEAT such as an examination of the impact of treatment on quality-of-life measures are ongoing.

A meta-analysis of 31 randomized trials comparing CPAP with various passive and active controls confirmed a significant effect of this treatment on blood pressure.[167] There was a highly significant net difference in systolic blood pressure (2.6 mm Hg) and in diastolic blood pressure (2.0 mm Hg) for CPAP compared with the control. In the studies that had 24-hour ambulatory blood pressure monitoring data available, the difference between treatment arms in systolic blood pressure was 2.2 mm Hg and in diastolic blood pressure was 1.9 mm Hg during the daytime period and 3.8 and 1.8 mm Hg, respectively, during the nighttime period. A higher AHI appeared to be associated with a greater decrease in systolic blood pressure. The results of this meta-analysis support that CPAP has a significant, albeit modest, effect on blood pressure.

Although most (but not all) studies and the above meta-analysis support a modest effect of CPAP on blood pressure, the effect on biomarkers associated with cardiovascular risk such as C-reactive protein has been more variable.[165,168–170] A recent randomized trial of CPAP versus best supportive care found that CPAP was associated with significant reductions in total and low-density lipoprotein cholesterol levels at 3 months but not at 12 months.[171] Such potentially beneficial effects on lipid-related parameters have not been consistently observed.[172] Further randomized study is needed of the effects of CPAP on cardiovascular risk factors and risk markers, although the most consistent and robust effect of CPAP to date appears to be on blood pressure.

Racial Disparities

Despite many advances in medicine, significant health disparities in the population remain. Many individuals belonging to racial/ethnic minority groups, and those who are socioeconomically disadvantaged face systematic discrepancies in their risk of adverse health outcomes and decreased life expectancy.[173,174] For example, the prevalence of obesity is higher among blacks than non-Hispanic whites.[175,176] In addition, rates of hypertension are much higher among blacks[177,178] and rates of diabetes mellitus are disproportionately higher among blacks and Hispanics/Latinos[179] than non-Hispanic whites. Race/ethnicity and socioeconomic status are important risk factors for cardiometabolic disease morbidity and mortality. As mentioned, sleep is associated with aspects of cardiometabolic disease and may represent an important risk factor for morbidity and mortality in these domains. It is important to note that in addition to cardiometabolic health disparities, racial/ethnic minorities are more likely to experience sleep duration outside of 7 to 8 hours, especially an SSD of ≤6 hours,[180–185] as well as increased prevalence of sleep disturbances,[186,187] and these relationships interact with socioeconomic status.[184,186,188,189] These relationships are consistent with the socio-ecological model of sleep and health, which places sleep at the interface of downstream cardiometabolic effects and upstream social/behavioral determinants.[188,190,191]

There is also emerging evidence that the relations between sleep and cardiometabolic disease risk factors may depend on race/ethnicity. For example, data from the CARDIA study (Coronary Artery Risk Development in Young Adults) showed that 5-year blood pressure change was mediated by race/ethnicity differences in sleep duration.[21] Additionally, data from NHANES showed that the U-shaped relationship between sleep duration and C-reactive protein levels was different across race/ethnicity groups, with a U-shaped relationship seen in non-Hispanic whites, elevations in short sleep seen in blacks, a pseudolinear relationship (lower levels in short sleep and higher levels in long sleep) seen in Asians/others, and no relation seen in Hispanics/Latinos.[192] Further data from NHANES showed that these 4 groups also differed in their relationships between habitual sleep duration and both subjectively and objectively determined prevalence of obesity, hypertension, hypercholesterolemia, and diabetes mellitus.[41] Although the specific reasons for these differences are not clear, previous work has shown that factors such as exposure to racism[193–198] and low childhood socioeconomic status,[199] as well as other factors,[188] may play roles.

Taken together, these results indicate that sleep may play an important role in health disparities and may represent a modifiable risk factor (along with diet and physical activity) for cardiometabolic risk in general and cardiometabolic health disparities specifically. Further research is needed to clarify these potential roles.

STATEMENT SUMMARY

Our review of the epidemiological data on the impact of sleep duration and disorders on cardiovascular health suggests the following:

1. Both short- and long-duration sleep and sleep disorders such as SDB and insomnia are associated with adverse cardiometabolic risk profiles and outcomes.
2. Sleep restriction has a negative impact on energy balance, but it is less clear whether treating sleep disorders has a positive impact on obesity risk.
3. Treating those with sleep disorders may provide clinical benefits, particularly for blood pressure.

CLINICAL RECOMMENDATIONS

The American Academy of Sleep Medicine and the Sleep Research Society recently released a statement in favor of ≥7 hours of sleep per night for adults "to promote optimal health."[191] Similarly, Healthy People 2020 has released a series of sleep health goals, including to "increase the proportion of adults who get sufficient sleep." To increase the clinical awareness of and action on sleep-related issues and disorders, the following steps should be considered:

1. The American Heart Association should directly address sleep behavior in a public health campaign to promote ideal cardiac health (akin to its Simple 7 campaign addressing blood pressure, cholesterol, blood sugar, physical activity, diet, weight, and smoking cessation).
2. A public health campaign addressing sleep behavior should include explicit guidelines for adequate sleep and suggestions for how to include screening for sleep duration and sleep disorders in routine clinical care and public health settings.
3. Existing simple assessment tools to screen for sleep apnea risk should be better integrated into routine clinical care and public health settings.

FUTURE RESEARCH PRIORITIES

The increase in observational and clinical studies examining the link between sleep duration and disorders and cardiometabolic health increases the likelihood that we may soon have clearer recommendations and guidelines that will influence clinical practice and public health campaigns. In addition, more research is needed, and research priorities include the following:

1. Inclusion of more diverse populations in research studies (ie, minorities, women, and overweight and obese participants)
2. Longer-term follow-up of participants in observational and clinical studies
3. Accurate and objective measures of sleep behavior, along with sleep architecture
4. Evaluations of the impact of other sleep disorders, notably restless leg syndrome and periodic limb movement disorder, on cardiometabolic risk
5. Development and evaluation of simple sleep behavior screening tools that could be used in busy clinical or public health settings
6. Evaluation of brief intervention strategies in busy clinical or public health settings

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FOOTNOTES

The American Heart Association makes every effort to avoid any actual or potential conflicts of interest that may arise as a result of an outside relationship or a personal, professional, or business interest of a member of the writing panel. Specifically, all members of the writing group are required to complete and submit a Disclosure Questionnaire showing all such relationships that might be perceived as real or potential conflicts of interest.

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*Modest.

†Significant.

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*Modest.

REFERENCES

1. Institute of Medicine Committee on Sleep Medicine and Research. *Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem*. Colten HR, Altevogt BM, eds. Washington, DC: National Academies Press; 2006.
2. Ohayon MM. Epidemiology of insomnia: what we know and what we still need to learn. *Sleep Med Rev*. 2002;6:97–111. doi: http://dx.doi.org/10.1053/smrv.2002.0186.
3. Peppard PE, Young T, Barnet JH, Palta M, Hagen EW, Hla KM. Increased prevalence of sleep-disordered breathing in adults. *Am J Epidemiol*. 2013;177:1006–1014. doi: 10.1093/aje/kws342.
4. Lavie P, Ben-Yosef R, Rubin AE. Prevalence of sleep apnea syndrome among patients with essential hypertension. *Am Heart J*. 1984;108:373–376.
5. Jhamb M, Unruh M. Bidirectional relationship of hypertension with obstructive sleep apnea. *Curr Opin Pulm Med*. 2014;20:558–564. doi: 10.1097/MCP.0000000000000102.
6. Canivet C, Nilsson PM, Lindeberg SI, Karasek R, Östergren PO. Insomnia increases risk for cardiovascular events in women and in men with low socioeconomic status: a longitudinal, register-based study. *J Psychosom Res*. 2014;76:292–299. doi: 10.1016/j.jpsychores.2014.02.001.
7. Faraut B, Touchette E, Gamble H, Royant-Parola S, Safar ME, Varsat B, Léger D. Short sleep duration and increased risk of hypertension: a primary care medicine investigation. *J Hypertens*. 2012;30:1354–1363. doi: 10.1097/HJH.0b013e32835465e5.
8. Friedman O, Bradley TD, Ruttanaumpawan P, Logan AG. Independent association of drug-resistant hypertension to reduced sleep duration and efficiency. *Am J Hypertens*. 2010;23:174–179. doi: 10.1038/ajh.2009.220.
9. Gangwisch JE, Heymsfield SB, Boden-Albala B, Buijs RM, Kreier F, Pickering TG, Rundle AG, Zammit GK, Malaspina D. Short sleep duration as a risk factor for hypertension: analyses of the first National Health and Nutrition Examination Survey. *Hypertension*. 2006;47:833–839. doi: 10.1161/01.HYP.0000217362.34748.e0.
10. Gangwisch JE, Heymsfield SB, Boden-Albala B, Buijs RM, Kreier F, Pickering TG, Rundle AG, Zammit GK, Malaspina D. Sleep duration as a risk factor for diabetes incidence in a large U.S. sample. *Sleep*. 2007;30:1667–1673.
11. Cappuccio FP, Stranges S, Kandala NB, Miller MA, Taggart FM, Kumari M, Ferrie JE, Shipley MJ, Brunner EJ, Marmot MG. Gender-specific associations of short sleep duration with prevalent and incident hypertension: the Whitehall II Study [published correction appears in *Hypertension*. 2007;50:e170]. *Hypertension*. 2007;50:693–700. doi: 10.1161/HYPERTENSIONAHA.107.095471.
12. Jackson CL, Redline S, Emmons KM. Sleep as a potential fundamental contributor to disparities in cardiovascular health. *Annu Rev Public Health*. 2015;36:417–440. doi: 10.1146/annurev-publhealth-031914-122838.
13. Guilleminault C, Tilkian A, Dement WC. The sleep apnea syndromes. *Annu Rev Med*. 1976;27:465–484. doi: 10.1146/annurev.me.27.020176.002341.
14. Redline S, Tishler PV, Hans MG, Tosteson TD, Strohl KP, Spry K. Racial differences in sleep-disordered breathing in African-Americans and Caucasians [published correction appears in *Am J Respir Crit Care Med*. 1997;155:1820]. *Am J Respir Crit Care Med*. 1997;155:186–192. doi: 10.1164/ajrccm.155.1.9001310.
15. Roth T. Insomnia: definition, prevalence, etiology, and consequences. *J Clin Sleep Med*. 2007;3(suppl):S7–S10.
16. Ohayon MM. Difficulty in resuming or inability to resume sleep and the links to daytime impairment: definition, prevalence and comorbidity. *J Psychiatr Res*. 2009;43:934–940. doi: 10.1016/j.jpsychires.2009.01.011.
17. Liu A, Kushida CA, Reaven GM. Risk for obstructive sleep apnea in obese, nondiabetic adults varies with insulin resistance status. *Sleep Breath*. 2013;17:333–338. doi: 10.1007/s11325-012-0696-0.
18. Grandner MA, Patel NP, Gehrman PR, Perlis ML, Pack AI. Problems associated with short sleep: bridging the gap between laboratory and epidemiological studies. *Sleep Med Rev*. 2010;14:239–247. doi: 10.1016/j.smrv.2009.08.001.
19. Jean-Louis G, Williams NJ, Sarpong D, Pandey A, Youngstedt S, Zizi F, Ogedegbe G. Associations between inadequate sleep and obesity in the US adult population: analysis of the national health interview survey (1977-2009). *BMC Public Health*. 2014;14:290. doi: 10.1186/1471-2458-14-290.
20. Gottlieb DJ, Redline S, Nieto FJ, Baldwin CM, Newman AB, Resnick HE, Punjabi NM. Association of usual sleep duration with hypertension: the Sleep Heart Health Study. *Sleep*. 2006;29:1009–1014.
21. Knutson KL, Van Cauter E, Rathouz PJ, Yan LL, Hulley SB, Liu K, Lauderdale DS. Association between sleep and blood pressure in midlife: the CARDIA sleep study. *Arch Intern Med*. 2009;169:1055–1061. doi: 10.1001/archinternmed.2009.119.

22. Stamatakis KA, Kaplan GA, Roberts RE. Short sleep duration across income, education, and race/ethnic groups: population prevalence and growing disparities during 34 years of follow-up. *Ann Epidemiol*. 2007;17:948–955. doi: 10.1016/j.annepidem.2007.07.096.
23. Bin YS, Marshall NS, Glozier N. Sleeping at the limits: the changing prevalence of short and long sleep durations in 10 countries. *Am J Epidemiol*. 2013;177:826–833. doi: 10.1093/aje/kws308.
24. Berkman LF, Buxton O, Ertel K, Okechukwu C. Managers' practices related to work-family balance predict employee cardiovascular risk and sleep duration in extended care settings. *J Occup Health Psychol*. 2010;15:316–329. doi: 10.1037/a0019721.
25. Chaput JP, Després JP, Bouchard C, Tremblay A. Association of sleep duration with type 2 diabetes and impaired glucose tolerance. *Diabetologia*. 2007;50:2298–2304. doi: 10.1007/s00125-007-0786-x.
26. Rafalson L, Donahue RP, Stranges S, Lamonte MJ, Dmochowski J, Dorn J, Trevisan M. Short sleep duration is associated with the development of impaired fasting glucose: the Western New York Health Study. *Ann Epidemiol*. 2010;20:883–889. doi: 10.1016/j.annepidem.2010.05.002.
27. Gangwisch JE. Epidemiological evidence for the links between sleep, circadian rhythms and metabolism. *Obes Rev*. 2009;10(suppl 2):37–45. doi: 10.1111/j.1467-789X.2009.00663.x.
28. Krueger PM, Friedman EM. Sleep duration in the United States: a cross-sectional population-based study. *Am J Epidemiol*. 2009;169:1052–1063. doi: 10.1093/aje/kwp023.
29. Cappuccio FP, Taggart FM, Kandala NB, Currie A, Peile E, Stranges S, Miller MA. Meta-analysis of short sleep duration and obesity in children and adults. *Sleep*. 2008;31:619–626.
30. Patel SR. Reduced sleep as an obesity risk factor. *Obes Rev*. 2009;10(suppl 2):61–68. doi: 10.1111/j.1467-789X.2009.00664.x.
31. Patel SR, Hu FB. Short sleep duration and weight gain: a systematic review. *Obesity (Silver Spring)*. 2008;16:643–653. doi: 10.1038/oby.2007.118.
32. Coughlin JW, Smith MT. Sleep, obesity, and weight loss in adults: is there a rationale for providing sleep interventions in the treatment of obesity? *Int Rev Psychiatry*. 2014;26:177–188. doi: 10.3109/09540261.2014.911150.
33. Depner CM, Stothard ER, Wright KP Jr. Metabolic consequences of sleep and circadian disorders. *Curr Diab Rep*. 2014;14:507. doi: 10.1007/s11892-014-0507-z.
34. St-Onge MP. The role of sleep duration in the regulation of energy balance: effects on energy intakes and expenditure. *J Clin Sleep Med*. 2013;9:73–80. doi: 10.5664/jcsm.2348.
35. Morselli LL, Guyon A, Spiegel K. Sleep and metabolic function. *Pflugers Arch*. 2012;463:139–160. doi: 10.1007/s00424-011-1053-z.
36. Knutson KL. Does inadequate sleep play a role in vulnerability to obesity? *Am J Hum Biol*. 2012;24:361–371. doi: 10.1002/ajhb.22219.
37. Lucassen EA, Rother KI, Cizza G. Interacting epidemics? Sleep curtailment, insulin resistance, and obesity. *Ann NY Acad Sci*. 2012;1264:110–134. doi: 10.1111/j.1749-6632.2012.06655.x.
38. Nielsen LS, Danielsen KV, Sørensen TI. Short sleep duration as a possible cause of obesity: critical analysis of the epidemiological evidence. *Obes Rev*. 2011;12:78–92. doi: 10.1111/j.1467-789X.2010.00724.x.
39. Altman NG, Izci-Balserak B, Schopfer E, Jackson N, Rattanaumpawan P, Gehrman PR, Patel NP, Grandner MA. Sleep duration versus sleep insufficiency as predictors of cardiometabolic health outcomes. *Sleep Med*. 2012;13:1261–1270. doi: 10.1016/j.sleep.2012.08.005.
40. Grandner MA, Schopfer EA, Sands-Lincoln M, Jackson N, Malhotra A. The relationship between sleep duration and body mass index depends on age. *Obesity (Silver Spring)*. 2015;23:2491–2498. doi: 10.1002/oby.21247.
41. Grandner MA, Chakravorty S, Perlis ML, Oliver L, Gurubhagavatula I. Habitual sleep duration associated with self-reported and objectively determined cardiometabolic risk factors. *Sleep Med*. 2014;15:42–50. doi: 10.1016/j.sleep.2013.09.012.
42. Börnhorst C, Hense S, Ahrens W, Hebestreit A, Reisch L, Barba G, von Kries R, Bayer O; IDEFICS Consortium. From sleep duration to childhood obesity: what are the pathways? *Eur J Pediatr*. 2012;171:1029–1038. doi: 10.1007/s00431-011-1670-8.
43. Jean-Louis G, Youngstedt S, Grandner M, Williams NJ, Sarpong D, Zizi F, Ogedegbe G. Unequal burden of sleep-related obesity among black and white Americans. *Sleep Health*. 2015;1:169–176.
44. Patel SR, Malhotra A, White DP, Gottlieb DJ, Hu FB. Association between reduced sleep and weight gain in women. *Am J Epidemiol*. 2006;164:947–954. doi: 10.1093/aje/kwj280.
45. Chaput JP, Després JP, Bouchard C, Tremblay A. The association between sleep duration and weight gain in adults: a 6-year prospective study from the Quebec Family Study. *Sleep*. 2008;31:517–523.
46. Watanabe M, Kikuchi H, Tanaka K, Takahashi M. Association of short sleep duration with weight gain and obesity at 1-year follow-up: a large-scale prospective study. *Sleep*. 2010;33:161–167.
47. Greer SM, Goldstein AN, Walker MP. The impact of sleep deprivation on food desire in the human brain. *Nat Commun*. 2013;4:2259. doi: 10.1038/ncomms3259.
48. Shechter A, Grandner MA, St-Onge MP. The role of sleep in the control of food intake. *Am J Lifestyle Med*. 2014;8:371–374. doi: 10.1177/1559827614545315.
49. Imaki M, Hatanaka Y, Ogawa Y, Yoshida Y, Tanada S. An epidemiological study on relationship between the hours of sleep and life style factors in Japanese factory workers. *J Physiol Anthropol Appl Human Sci*. 2002;21:115–120.
50. Grandner MA, Kripke DF, Naidoo N, Langer RD. Relationships among dietary nutrients and subjective sleep, objective sleep, and napping in women. *Sleep Med*. 2010;11:180–184. doi: 10.1016/j.sleep.2009.07.014.
51. Grandner MA, Jackson N, Gerstner JR, Knutson KL. Dietary nutrients associated with short and long sleep duration: data from a nationally representative sample. *Appetite*. 2013;64:71–80. doi: 10.1016/j.appet.2013.01.004.
52. Grandner MA, Jackson NJ, Izci-Balserak B, Gallagher RA, Murray-Bachmann R, Williams NJ, Patel NP, Jean-Louis G. Social and behavioral determinants of perceived insufficient sleep. *Front Neurol*. 2015;6:112. doi: 10.3389/fneur.2015.00112.
53. Grandner MA, Patel NP, Perlis ML, Gehrman PR, Xie D, Sha D, Pigeon WR, Teff K, Weaver T, Gooneratne NS. Obesity, diabetes, and exercise associated with sleep-related complaints in the American population. *Z Gesundh Wiss*. 2011;19:463–474. doi: 10.1007/s10389-011-0398-2.
54. Buman MP, Hekler EB, Bliwise DL, King AC. Exercise effects on night-to-night fluctuations in self-rated sleep among older adults with sleep complaints. *J Sleep Res*. 2011;20(pt 1):28–37. doi: 10.1111/j.1365-2869.2010.00866.x.
55. Xiao Q, Keadle SK, Hollenbeck AR, Matthews CE. Sleep duration and total and cause-specific mortality in a large US cohort: interrelationships with physical activity, sedentary behavior, and body mass index. *Am J Epidemiol*. 2014;180:997–1006. doi: 10.1093/aje/kwu222.
56. Calvin AD, Carter RE, Adachi T, Macedo PG, Albuquerque FN, van der Walt C, Bukartyk J, Davison DE, Levine JA, Somers VK. Effects of experimental sleep restriction on caloric intake and activity energy expenditure. *Chest*. 2013;144:79–86. doi: 10.1378/chest.12-2829.
57. Bosy-Westphal A, Hinrichs S, Jauch-Chara K, Hitze B, Later W, Wilms B, Settler U, Peters A, Kiosz D, Muller MJ. Influence of

partial sleep deprivation on energy balance and insulin sensitivity in healthy women. *Obes Facts*. 2008;1:266–273. doi: 10.1159/000158874.
58. Brondel L, Romer MA, Nougues PM, Touyarou P, Davenne D. Acute partial sleep deprivation increases food intake in healthy men. *Am J Clin Nutr*. 2010;91:1550–1559. doi: 10.3945/ajcn.2009.28523.
59. Markwald RR, Melanson EL, Smith MR, Higgins J, Perreault L, Eckel RH, Wright KP Jr. Impact of insufficient sleep on total daily energy expenditure, food intake, and weight gain. *Proc Natl Acad Sci USA*. 2013;110:5695–700. doi: 10.1073/pnas.1216951110.
60. Nedeltcheva AV, Kilkus JM, Imperial J, Kasza K, Schoeller DA, Penev PD. Sleep curtailment is accompanied by increased intake of calories from snacks. *Am J Clin Nutr*. 2009;89:126–133. doi: 10.3945/ajcn.2008.26574.
61. Spaeth AM, Dinges DF, Goel N. Effects of experimental sleep restriction on weight gain, caloric intake, and meal timing in healthy adults. *Sleep*. 2013;36:981–990. doi: 10.5665/sleep.2792.
62. St-Onge MP, Roberts AL, Chen J, Kelleman M, O'Keeffe M, RoyChoudhury A, Jones PJ. Short sleep duration increases energy intakes but does not change energy expenditure in normal-weight individuals. *Am J Clin Nutr*. 2011;94:410–416. doi: 10.3945/ajcn.111.013904.
63. Benedict C, Hallschmid M, Lassen A, Mahnke C, Schultes B, Schiöth HB, Born J, Lange T. Acute sleep deprivation reduces energy expenditure in healthy men. *Am J Clin Nutr*. 2011;93:1229–1236. doi: 10.3945/ajcn.110.006460.
64. Schmid SM, Hallschmid M, Jauch-Chara K, Wilms B, Benedict C, Lehnert H, Born J, Schultes B. Short-term sleep loss decreases physical activity under free-living conditions but does not increase food intake under time-deprived laboratory conditions in healthy men. *Am J Clin Nutr*. 2009;90:1476–1482. doi: 10.3945/ajcn.2009.27984.
65. Reynolds AC, Dorrian J, Liu PY, Van Dongen HP, Wittert GA, Harmer LJ, Banks S. Impact of five nights of sleep restriction on glucose metabolism, leptin and testosterone in young adult men. *PLoS One*. 2012;7:e41218. doi: 10.1371/journal.pone.0041218.
66. van Leeuwen WM, Hublin C, Sallinen M, Härmä M, Hirvonen A, Porkka-Heiskanen T. Prolonged sleep restriction affects glucose metabolism in healthy young men. *Int J Endocrinol*. 2010;2010:108641. doi: 10.1155/2010/108641.
67. Pejovic S, Vgontzas AN, Basta M, Tsaoussoglou M, Zoumakis E, Vgontzas A, Bixler EO, Chrousos GP. Leptin and hunger levels in young healthy adults after one night of sleep loss. *J Sleep Res*. 2010;19:552–558. doi: 10.1111/j.1365-2869.2010.00844.x.
68. Simpson NS, Banks S, Dinges DF. Sleep restriction is associated with increased morning plasma leptin concentrations, especially in women. *Biol Res Nurs*. 2010;12:47–53. doi: 10.1177/1099800410366301.
69. Buxton OM, Cain SW, O'Connor SP, Porter JH, Duffy JF, Wang W, Czeisler CA, Shea SA. Adverse metabolic consequences in humans of prolonged sleep restriction combined with circadian disruption. *Sci Transl Med*. 2012;4:129ra43. doi: 10.1126/scitranslmed.3003200.
70. Spiegel K, Tasali E, Penev P, Van Cauter E. 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*. 2004;141:846–850.
71. Gonnissen HK, Hursel R, Rutters F, Martens EA, Westerterp-Plantenga MS. Effects of sleep fragmentation on appetite and related hormone concentrations over 24 h in healthy men. *Br J Nutr*. 2013;109:748–756. doi: 10.1017/S0007114512001894.
72. St-Onge MP, O'Keeffe M, Roberts AL, RoyChoudhury A, Laferrère B. Short sleep duration, glucose dysregulation and hormonal regulation of appetite in men and women. *Sleep*. 2012;35:1503–1510. doi: 10.5665/sleep.2198.
73. Nedeltcheva AV, Kilkus JM, Imperial J, Schoeller DA, Penev PD. Insufficient sleep undermines dietary efforts to reduce adiposity. *Ann Intern Med*. 2010;153:435–441. doi: 10.7326/0003-4819-153-7-201010050-00006.
74. Hogenkamp PS, Nilsson E, Nilsson VC, Chapman CD, Vogel H, Lundberg LS, Zarei S, Cedernaes J, Rångtell FH, Broman JE, Dickson SL, Brunstrom JM, Benedict C, Schiöth HB. Acute sleep deprivation increases portion size and affects food choice in young men. *Psychoneuroendocrinology*. 2013;38:1668–1674. doi: 10.1016/j.psyneuen.2013.01.012.
75. St-Onge MP, McReynolds A, Trivedi ZB, Roberts AL, Sy M, Hirsch J. Sleep restriction leads to increased activation of brain regions sensitive to food stimuli. *Am J Clin Nutr*. 2012;95:818–824. doi: 10.3945/ajcn.111.027383.
76. St-Onge MP, Wolfe S, Sy M, Shechter A, Hirsch J. Sleep restriction increases the neuronal response to unhealthy food in normal-weight individuals. *Int J Obes (Lond)*. 2014;38:411–416. doi: 10.1038/ijo.2013.114.
77. Benedict C, Brooks SJ, O'Daly OG, Almèn MS, Morell A, Åberg K, Gingnell M, Schultes B, Hallschmid M, Broman JE, Larsson EM, Schiöth HB. Acute sleep deprivation enhances the brain's response to hedonic food stimuli: an fMRI study. *J Clin Endocrinol Metab*. 2012;97:E443–E447. doi: 10.1210/jc.2011-2759.
78. Chapman CD, Nilsson EK, Nilsson VC, Cedernaes J, Rångtell FH, Vogel H, Dickson SL, Broman JE, Hogenkamp PS, Schiöth HB, Benedict C. Acute sleep deprivation increases food purchasing in men. *Obesity (Silver Spring)*. 2013;21:E555–E560. doi: 10.1002/oby.20579.
79. Shechter A, Rising R, Wolfe S, Albu JB, St-Onge MP. Postprandial thermogenesis and substrate oxidation are unaffected by sleep restriction. *Int J Obes (Lond)*. 2014;38:1153–1158. doi: 10.1038/ijo.2013.239.
80. Hursel R, Rutters F, Gonnissen HK, Martens EA, Westerterp-Plantenga MS. Effects of sleep fragmentation in healthy men on energy expenditure, substrate oxidation, physical activity, and exhaustion measured over 48 h in a respiratory chamber. *Am J Clin Nutr*. 2011;94:804–808. doi: 10.3945/ajcn.111.017632.
81. Buxton OM, Pavlova M, Reid EW, Wang W, Simonson DC, Adler GK. Sleep restriction for 1 week reduces insulin sensitivity in healthy men. *Diabetes*. 2010;59:2126–2133. doi: 10.2337/db09-0699.
82. Jung CM, Melanson EL, Frydendall EJ, Perreault L, Eckel RH, Wright KP. Energy expenditure during sleep, sleep deprivation and sleep following sleep deprivation in adult humans. *J Physiol*. 2011;589(pt 1):235–244. doi: 10.1113/jphysiol.2010.197517.
83. Shechter A, Rising R, Albu JB, St-Onge MP. Experimental sleep curtailment causes wake-dependent increases in 24-h energy expenditure as measured by whole-room indirect calorimetry. *Am J Clin Nutr*. 2013;98:1433–1439. doi: 10.3945/ajcn.113.069427.
84. Robertson MD, Russell-Jones D, Umpleby AM, Dijk DJ. Effects of three weeks of mild sleep restriction implemented in the home environment on multiple metabolic and endocrine markers in healthy young men. *Metabolism*. 2013;62:204–211. doi: 10.1016/j.metabol.2012.07.016.
85. Arora T, Jiang CQ, Thomas GN, Lam KB, Zhang WS, Cheng KK, Lam TH, Taheri S. Self-reported long total sleep duration is associated with metabolic syndrome: the Guangzhou Biobank Cohort Study. *Diabetes Care*. 2011;34:2317–2319. doi: 10.2337/dc11-0647.
86. Chaput JP, McNeil J, Després JP, Bouchard C, Tremblay A. Short sleep duration as a risk factor for the development of the metabolic syndrome in adults. *Prev Med*. 2013;57:872–877. doi: 10.1016/j.ypmed.2013.09.022.
87. Choi KM, Lee JS, Park HS, Baik SH, Choi DS, Kim SM. Relationship between sleep duration and the metabolic syndrome: Korean National Health and Nutrition Survey 2001. *Int J Obes (Lond)*. 2008;32:1091–1097. doi: 10.1038/ijo.2008.62.

88. Choi JK, Kim MY, Kim JK, Park JK, Oh SS, Koh SB, Eom A. Association between short sleep duration and high incidence of metabolic syndrome in midlife women. *Tohoku J Exp Med*. 2011;225:187–193.
89. Hall MH, Muldoon MF, Jennings JR, Buysse DJ, Flory JD, Manuck SB. Self-reported sleep duration is associated with the metabolic syndrome in midlife adults. *Sleep*. 2008;31:635–643.
90. Kobayashi D, Takahashi O, Deshpande GA, Shimbo T, Fukui T. Relation between metabolic syndrome and sleep duration in Japan: a large scale cross-sectional study. *Intern Med*. 2011;50:103–107.
91. McCanlies EC, Slaven JE, Smith LM, Andrew ME, Charles LE, Burchfiel CM, Violanti JM. Metabolic syndrome and sleep duration in police officers. *Work*. 2012;43:133–139. doi: 10.3233/WOR-2012-1399.
92. Cappuccio FP, D'Elia L, Strazzullo P, Miller MA. Quantity and quality of sleep and incidence of type 2 diabetes: a systematic review and meta-analysis. *Diabetes Care*. 2010;33:414–420. doi: 10.2337/dc09-1124.
93. Holliday EG, Magee CA, Kritharides L, Banks E, Attia J. Short sleep duration is associated with risk of future diabetes but not cardiovascular disease: a prospective study and meta-analysis. *PLoS One*. 2013;8:e82305. doi: 10.1371/journal.pone.0082305.
94. Meng L, Zheng Y, Hui R. The relationship of sleep duration and insomnia to risk of hypertension incidence: a meta-analysis of prospective cohort studies. *Hypertens Res*. 2013;36:985–995. doi: 10.1038/hr.2013.70.
95. Guo X, Zheng L, Wang J, Zhang X, Zhang X, Li J, Sun Y. Epidemiological evidence for the link between sleep duration and high blood pressure: a systematic review and meta-analysis. *Sleep Med*. 2013;14:324–332. doi: 10.1016/j.sleep.2012.12.001.
96. Wang Q, Xi B, Liu M, Zhang Y, Fu M. Short sleep duration is associated with hypertension risk among adults: a systematic review and meta-analysis. *Hypertens Res*. 2012;35:1012–1018. doi: 10.1038/hr.2012.91.
97. Cappuccio FP, Cooper D, D'Elia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. *Eur Heart J*. 2011;32:1484–1492. doi: 10.1093/eurheartj/ehr007.
98. Garde AH, Hansen ÅM, Holtermann A, Gyntelberg F, Suadicani P. Sleep duration and ischemic heart disease and all-cause mortality: prospective cohort study on effects of tranquilizers/hypnotics and perceived stress. *Scand J Work Environ Health*. 2013;39:550–558. doi: 10.5271/sjweh.3372.
99. Broussard JL, Ehrmann DA, Van Cauter E, Tasali E, Brady MJ. Impaired insulin signaling in human adipocytes after experimental sleep restriction: a randomized, crossover study. *Ann Intern Med*. 2012;157:549–557. doi: 10.7326/0003-4819-157-8-201210160-00005.
100. Ford ES, Wheaton AG, Chapman DP, Li C, Perry GS, Croft JB. Associations between self-reported sleep duration and sleeping disorder with concentrations of fasting and 2-h glucose, insulin, and glycosylated hemoglobin among adults without diagnosed diabetes. *J Diabetes*. 2014;6:338–350. doi: 10.1111/1753-0407.12101.
101. Nedeltcheva AV, Kessler L, Imperial J, Penev PD. Exposure to recurrent sleep restriction in the setting of high caloric intake and physical inactivity results in increased insulin resistance and reduced glucose tolerance. *J Clin Endocrinol Metab*. 2009;94:3242–3250. doi: 10.1210/jc.2009-0483.
102. Robillard R, Lanfranchi PA, Prince F, Filipini D, Carrier J. Sleep deprivation increases blood pressure in healthy normotensive elderly and attenuates the blood pressure response to orthostatic challenge. *Sleep*. 2011;34:335–339.
103. Borel AL, Pépin JL, Nasse L, Baguet JP, Netter S, Benhamou PY. Short sleep duration measured by wrist actimetry is associated with deteriorated glycemic control in type 1 diabetes. *Diabetes Care*. 2013;36:2902–2908. doi: 10.2337/dc12-2038.
104. Friedman O, Shukla Y, Logan AG. Relationship between self-reported sleep duration and changes in circadian blood pressure. *Am J Hypertens*. 2009;22:1205–1211. doi: 10.1038/ajh.2009.165.
105. Dettoni JL, Consolim-Colombo FM, Drager LF, Rubira MC, Souza SB, Irigoyen MC, Mostarda C, Borile S, Krieger EM, Moreno H Jr, Lorenzi-Filho G. Cardiovascular effects of partial sleep deprivation in healthy volunteers. *J Appl Physiol (1985)*. 2012;113:232–236. doi: 10.1152/japplphysiol.01604.2011.
106. Frey DJ, Fleshner M, Wright KP Jr. The effects of 40 hours of total sleep deprivation on inflammatory markers in healthy young adults. *Brain Behav Immun*. 2007;21:1050–1057. doi: 10.1016/j.bbi.2007.04.003.
107. van Leeuwen WM, Lehto M, Karisola P, Lindholm H, Luukkonen R, Sallinen M, Härmä M, Porkka-Heiskanen T, Alenius H. Sleep restriction increases the risk of developing cardiovascular diseases by augmenting proinflammatory responses through IL-17 and CRP. *PLoS One*. 2009;4:e4589. doi: 10.1371/journal.pone.0004589.
108. Wang X, Bi Y, Zhang Q, Pan F. Obstructive sleep apnoea and the risk of type 2 diabetes: a meta-analysis of prospective cohort studies. *Respirology*. 2013;18:140–146. doi: 10.1111/j.1440-1843.2012.02267.x.
109. Phillips B, Mannino DM. Do insomnia complaints cause hypertension or cardiovascular disease? *J Clin Sleep Med*. 2007;3:489–494.
110. Phillips B, Bůzková P, Enright P; Cardiovascular Health Study Research Group. Insomnia did not predict incident hypertension in older adults in the Cardiovascular Health Study. *Sleep*. 2009;32:65–72. doi:
111. Fernandez-Mendoza J, Vgontzas AN, Liao D, Shaffer ML, Vela-Bueno A, Basta M, Bixler EO. Insomnia with objective short sleep duration and incident hypertension: the Penn State Cohort. *Hypertension*. 2012;60:929–935. doi: 10.1161/HYPERTENSIONAHA.112.193268.
112. Gangwisch JE, Malaspina D, Posner K, Babiss LA, Heymsfield SB, Turner JB, Zammit GK, Pickering TG. Insomnia and sleep duration as mediators of the relationship between depression and hypertension incidence. *Am J Hypertens*. 2010;23:62–69. doi: 10.1038/ajh.2009.202.
113. Somers VK, White DP, Amin R, Abraham WT, Costa F, Culebras A, Daniels S, Floras JS, Hunt CE, Olson LJ, Pickering TG, Russell R, Woo M, Young T. Sleep apnea and cardiovascular disease: an American Heart Association/American College of Cardiology Foundation scientific statement from the American Heart Association Council for High Blood Pressure Research Professional Education Committee, Council on Clinical Cardiology, Stroke Council, and Council on Cardiovascular Nursing [published correction appears in *Circulation*. 2009;119:e380]. *Circulation*. 2008;118:1080–1111. doi: 10.1161/CIRCULATIONAHA.107.189375.
114. Guillot M, Sforza E, Achour-Crawford E, Maudoux D, Saint-Martin M, Barthélémy JC, Roche F. Association between severe obstructive sleep apnea and incident arterial hypertension in the older people population. *Sleep Med*. 2013;14:838–842. doi: 10.1016/j.sleep.2013.05.002.
115. Cano-Pumarega I, Durán-Cantolla J, Aizpuru F, Miranda-Serrano E, Rubio R, Martínez-Null C, de Miguel J, Egea C, Cancelo L, Alvarez A, Fernández-Bolaños M, Barbé F. Obstructive sleep apnea and systemic hypertension: longitudinal study in the general population: the Vitoria Sleep Cohort. *Am J Respir Crit Care Med*. 2011;184:1299–1304. doi: 10.1164/rccm.201101-0130OC.
116. O'Connor GT, Caffo B, Newman AB, Quan SF, Rapoport DM, Redline S, Resnick HE, Samet J, Shahar E. Prospective study of sleep-disordered breathing and hypertension: the Sleep Heart

Health Study. *Am J Respir Crit Care Med*. 2009;179:1159–1164. doi: 10.1164/rccm.200712-1809OC.
117. Chandola T, Ferrie JE, Perski A, Akbaraly T, Marmot MG. The effect of short sleep duration on coronary heart disease risk is greatest among those with sleep disturbance: a prospective study from the Whitehall II cohort. *Sleep*. 2010;33:739–744.
118. Laugsand LE, Vatten LJ, Platou C, Janszky I. Insomnia and the risk of acute myocardial infarction: a population study. *Circulation*. 2011;124:2073–2081. doi: 10.1161/CIRCULATIONAHA.111.025858.
119. Meisinger C, Heier M, Löwel H, Schneider A, Döring A. Sleep duration and sleep complaints and risk of myocardial infarction in middle-aged men and women from the general population: the MONICA/KORA Augsburg cohort study. *Sleep*. 2007;30:1121–1127.
120. Elwood P, Hack M, Pickering J, Hughes J, Gallacher J. Sleep disturbance, stroke, and heart disease events: evidence from the Caerphilly cohort. *J Epidemiol Community Health*. 2006;60:69–73. doi: 10.1136/jech.2005.039057.
121. Sivertsen B, Lallukka T, Salo P, Pallesen S, Hysing M, Krokstad S, Øverland S. Insomnia as a risk factor for ill health: results from the large population-based prospective HUNT Study in Norway. *J Sleep Res*. 2014;23:124–132. doi: 10.1111/jsr.12102.
122. Wu MP, Lin HJ, Weng SF, Ho CH, Wang JJ, Hsu YW. Insomnia subtypes and the subsequent risks of stroke: report from a nationally representative cohort. *Stroke*. 2014;45:1349–1354. doi: 10.1161/STROKEAHA.113.003675.
123. Sofi F, Cesari F, Casini A, Macchi C, Abbate R, Gensini GF. Insomnia and risk of cardiovascular disease: a meta-analysis. *Eur J Prev Cardiol*. 2014;21:57–64. doi: 10.1177/2047487312460020.
124. Hoevenaar-Blom MP, Spijkerman AM, Kromhout D, van den Berg JF, Verschuren WM. Sleep duration and sleep quality in relation to 12-year cardiovascular disease incidence: the MORGEN study. *Sleep*. 2011;34:1487–1492. doi: 10.5665/sleep.1382.
125. Loke YK, Brown JW, Kwok CS, Niruban A, Myint PK. Association of obstructive sleep apnea with risk of serious cardiovascular events: a systematic review and meta-analysis. *Circ Cardiovasc Qual Outcomes*. 2012;5:720–728. doi: 10.1161/CIRCOUTCOMES.111.964783.
126. Wang X, Ouyang Y, Wang Z, Zhao G, Liu L, Bi Y. Obstructive sleep apnea and risk of cardiovascular disease and all-cause mortality: a meta-analysis of prospective cohort studies. *Int J Cardiol*. 2013;169:207–214. doi: 10.1016/j.ijcard.2013.08.088.
127. Dong JY, Zhang YH, Qin LQ. Obstructive sleep apnea and cardiovascular risk: meta-analysis of prospective cohort studies. *Atherosclerosis*. 2013;229:489–495. doi: 10.1016/j.atherosclerosis.2013.04.026.
128. Campos-Rodriguez F, Martinez-Garcia MA, Reyes-Nuñez N, Caballero-Martinez I, Catalan-Serra P, Almeida-Gonzalez CV. Role of sleep apnea and continuous positive airway pressure therapy in the incidence of stroke or coronary heart disease in women. *Am J Respir Crit Care Med*. 2014;189:1544–1550. doi: 10.1164/rccm.201311-2012OC.
129. Li M, Hou WS, Zhang XW, Tang ZY. Obstructive sleep apnea and risk of stroke: a meta-analysis of prospective studies. *Int J Cardiol*. 2014;172:466–469. doi: 10.1016/j.ijcard.2013.12.230.
130. Winter AC, Schürks M, Glynn RJ, Buring JE, Gaziano JM, Berger K, Kurth T. Restless legs syndrome and risk of incident cardiovascular disease in women and men: prospective cohort study. *BMJ Open*. 2012;2:e000866. doi: 10.1136/bmjopen-2012-000866.
131. Li Y, Walters AS, Chiuve SE, Rimm EB, Winkelman JW, Gao X. Prospective study of restless legs syndrome and coronary heart disease among women. *Circulation*. 2012;126:1689–1694. doi: 10.1161/CIRCULATIONAHA.112.112698.
132. La Manna G, Pizza F, Persici E, Baraldi O, Comai G, Cappuccilli ML, Centofanti F, Carretta E, Plazzi G, Colì L, Montagna P, Stefoni S. Restless legs syndrome enhances cardiovascular risk and mortality in patients with end-stage kidney disease undergoing long-term haemodialysis treatment. *Nephrol Dial Transplant*. 2011;26:1976–1983. doi: 10.1093/ndt/gfq681.
133. Kendzerska T, Gershon AS, Hawker G, Leung RS, Tomlinson G. Obstructive sleep apnea and risk of cardiovascular events and all-cause mortality: a decade-long historical cohort study. *PLoS Med*. 2014;11:e1001599. doi: 10.1371/journal.pmed.1001599.
134. Koo BB, Blackwell T, Ancoli-Israel S, Stone KL, Stefanick ML, Redline S; Osteoporotic Fractures in Men (MrOS) Study Group. Association of incident cardiovascular disease with periodic limb movements during sleep in older men: Outcomes of Sleep Disorders in Older Men (MrOS) Study. *Circulation*. 2011;124:1223–1231. doi: 10.1161/CIRCULATIONAHA.111.038968.
135. Haack M, Serrador J, Cohen D, Simpson N, Meier-Ewert H, Mullington JM. Increasing sleep duration to lower beat-to-beat blood pressure: a pilot study. *J Sleep Res*. 2013;22:295–304. doi: 10.1111/jsr.12011.
136. Irwin MR, Olmstead R, Carrillo C, Sadeghi N, Breen EC, Witarama T, Yokomizo M, Lavretsky H, Carroll JE, Motivala SJ, Bootzin R, Nicassio P. Cognitive behavioral therapy vs. Tai Chi for late life insomnia and inflammatory risk: a randomized controlled comparative efficacy trial. *Sleep*. 2014;37:1543–1552. doi: 10.5665/sleep.4008.
137. Foster GD, Borradaile KE, Sanders MH, Millman R, Zammit G, Newman AB, Wadden TA, Kelley D, Wing RR, Pi-Sunyer FX, Reboussin D, Kuna ST; Sleep AHEAD Research Group of Look AHEAD Research Group. A randomized study on the effect of weight loss on obstructive sleep apnea among obese patients with type 2 diabetes: the Sleep AHEAD study. *Arch Intern Med*. 2009;169:1619–1626. doi: 10.1001/archinternmed.2009.266.
138. Fredheim JM, Rollheim J, Sandbu R, Hofsø D, Omland T, Røislien J, Hjelmesæth J. Obstructive sleep apnea after weight loss: a clinical trial comparing gastric bypass and intensive lifestyle intervention. *J Clin Sleep Med*. 2013;9:427–432. doi: 10.5664/jcsm.2656.
139. Johansson K, Neovius M, Lagerros YT, Harlid R, Rössner S, Granath F, Hemmingsson E. Effect of a very low energy diet on moderate and severe obstructive sleep apnoea in obese men: a randomised controlled trial. *BMJ*. 2009;339:b4609.
140. Kemppainen T, Ruoppi P, Seppä J, Sahlman J, Peltonen M, Tukiainen H, Gylling H, Vanninen E, Tuomilehto H. Effect of weight reduction on rhinometric measurements in overweight patients with obstructive sleep apnea. *Am J Rhinol*. 2008;22:410–415. doi: 10.2500/ajr.2008.22.3203.
141. Hernandez TL, Ballard RD, Weil KM, Shepard TY, Scherzinger AL, Stamm ER, Sharp TA, Eckel RH. Effects of maintained weight loss on sleep dynamics and neck morphology in severely obese adults. *Obesity (Silver Spring)*. 2009;17:84–91. doi: 10.1038/oby.2008.485.
142. Phillips CL, Yee BJ, Trenell MI, Magnussen JS, Wang D, Banerjee D, Berend N, Grunstein RR. Changes in regional adiposity and cardio-metabolic function following a weight loss program with sibutramine in obese men with obstructive sleep apnea. *J Clin Sleep Med*. 2009;5:416–421.
143. Barnes M, Goldsworthy UR, Cary BA, Hill CJ. A diet and exercise program to improve clinical outcomes in patients with obstructive sleep apnea: a feasibility study. *J Clin Sleep Med*. 2009;5:409–415.
144. Yan E, Ko E, Luong V, Wang HJ, Romanova M, Li Z. Long-term changes in weight loss and obesity-related comorbidities after Roux-en-Y gastric bypass: a primary care experience. *Am J Surg*. 2008;195:94–98. doi: 10.1016/j.amjsurg.2007.01.036.
145. Zhang N, Maffei A, Cerabona T, Pahuja A, Omana J, Kaul A. Reduction in obesity-related comorbidities: is gastric bypass

better than sleeve gastrectomy? *Surg Endosc*. 2013;27:1273–1280. doi: 10.1007/s00464-012-2595-7.
146. Varela JE, Hinojosa MW, Nguyen NT. Resolution of obstructive sleep apnea after laparoscopic gastric bypass. *Obes Surg*. 2007;17:1279–1282. doi: 10.1007/s11695-007-9228-6.
147. Dixon JB, Schachter LM, O'Brien PE. Polysomnography before and after weight loss in obese patients with severe sleep apnea. *Int J Obes (Lond)*. 2005;29:1048–1054. doi: 10.1038/sj.ijo.0802960.
148. Omana JJ, Nguyen SQ, Herron D, Kini S. Comparison of comorbidity resolution and improvement between laparoscopic sleeve gastrectomy and laparoscopic adjustable gastric banding. *Surg Endosc*. 2010;24:2513–2517. doi: 10.1007/s00464-010-0995-0.
149. Ravesloot MJ, Hilgevoord AA, van Wagensveld BA, de Vries N. Assessment of the effect of bariatric surgery on obstructive sleep apnea at two postoperative intervals. *Obes Surg*. 2014;24:22–31. doi: 10.1007/s11695-013-1023-y.
150. Wong SK, So WY, Yau PY, Chan AK, Lee S, Chan PN, Chow FC, Chung SS. Laparoscopic adjustable gastric banding for the treatment of morbidly obese patients: early outcome in a Chinese cohort. *Hong Kong Med J*. 2005;11:20–29.
151. Peluso L, Vanek VW. Efficacy of gastric bypass in the treatment of obesity-related comorbidities. *Nutr Clin Pract*. 2007;22:22–28.
152. Fritscher LG, Canani S, Mottin CC, Fritscher CC, Berleze D, Chapman K, Chatkin JM. Bariatric surgery in the treatment of obstructive sleep apnea in morbidly obese patients. *Respiration*. 2007;74:647–652. doi: 10.1159/000107736.
153. Kardassis D, Grote L, Sjöström L, Hedner J, Karason K. Sleep apnea modifies the long-term impact of surgically induced weight loss on cardiac function and inflammation. *Obesity (Silver Spring)*. 2013;21:698–704. doi: 10.1002/oby.20115.
154. Lankford DA, Proctor CD, Richard R. Continuous positive airway pressure (CPAP) changes in bariatric surgery patients undergoing rapid weight loss. *Obes Surg*. 2005;15:336–341. doi: 10.1381/0960892053576749.
155. Behrens C, Tang BQ, Amson BJ. Early results of a Canadian laparoscopic sleeve gastrectomy experience. *Can J Surg*. 2011;54:138–143. doi: 10.1503/cjs.041209.
156. Ou Yang O, Loi K, Liew V, Talbot M, Jorgensen J. Staged laparoscopic sleeve gastrectomy followed by Roux-en-Y gastric bypass for morbidly obese patients: a risk reduction strategy. *Obes Surg*. 2008;18:1575–1580. doi: 10.1007/s11695-008-9554-3.
157. Busetto L, Enzi G, Inelmen EM, Costa G, Negrin V, Sergi G, Vianello A. Obstructive sleep apnea syndrome in morbid obesity: effects of intragastric balloon. *Chest*. 2005;128:618–623. doi: 10.1378/chest.128.2.618.
158. Rawlins L, Rawlins MP, Brown CC, Schumacher DL. Sleeve gastrectomy: 5-year outcomes of a single institution. *Surg Obes Relat Dis*. 2013;9:21–25. doi: 10.1016/j.soard.2012.08.014.
159. Anandam A, Akinnusi M, Kufel T, Porhomayon J, El-Solh AA. Effects of dietary weight loss on obstructive sleep apnea: a meta-analysis. *Sleep Breath*. 2013;17:227–234. doi: 10.1007/s11325-012-0677-3.
160. Araghi MH, Chen YF, Jagielski A, Choudhury S, Banerjee D, Hussain S, Thomas GN, Taheri S. Effectiveness of lifestyle interventions on obstructive sleep apnea (OSA): systematic review and meta-analysis. *Sleep*. 2013;36:1553–1562, 1562A–1562E. doi: 10.5665/sleep.3056.
161. Gottlieb DJ, Yenokyan G, Newman AB, O'Connor GT, Punjabi NM, Quan SF, Redline S, Resnick HE, Tong EK, Diener-West M, Shahar E. Prospective study of obstructive sleep apnea and incident coronary heart disease and heart failure: the Sleep Heart Health Study. *Circulation*. 2010;122:352–360. doi: 10.1161/CIRCULATIONAHA.109.901801.
162. Marin JM, Carrizo SJ, Vicente E, Agusti AG. Long-term cardiovascular outcomes in men with obstructive sleep apnoea-hypopnoea with or without treatment with continuous positive airway pressure: an observational study. *Lancet*. 2005;365:1046–1053. doi: 10.1016/S0140-6736(05)71141-7.
163. Marin JM, Agusti A, Villar I, Forner M, Nieto D, Carrizo SJ, Barbé F, Vicente E, Wei Y, Nieto FJ, Jelic S. Association between treated and untreated obstructive sleep apnea and risk of hypertension. *JAMA*. 2012;307:2169–2176. doi: 10.1001/jama.2012.3418.
164. Punjabi NM, Caffo BS, Goodwin JL, Gottlieb DJ, Newman AB, O'Connor GT, Rapoport DM, Redline S, Resnick HE, Robbins JA, Shahar E, Unruh ML, Samet JM. Sleep-disordered breathing and mortality: a prospective cohort study. *PLoS Med*. 2009;6:e1000132. doi: 10.1371/journal.pmed.1000132.
165. Gottlieb DJ, Punjabi NM, Mehra R, Patel SR, Quan SF, Babineau DC, Tracy RP, Rueschman M, Blumenthal RS, Lewis EF, Bhatt DL, Redline S. CPAP versus oxygen in obstructive sleep apnea. *N Engl J Med*. 2014;370:2276–2285. doi: 10.1056/NEJMoa1306766.
166. Netzer NC, Stoohs RA, Netzer CM, Clark K, Strohl KP. Using the Berlin Questionnaire to identify patients at risk for the sleep apnea syndrome. *Ann Intern Med*. 1999;131:485–491.
167. Fava C, Dorigoni S, Dalle Vedove F, Danese E, Montagnana M, Guidi GC, Narkiewicz K, Minuz P. Effect of CPAP on blood pressure in patients with OSA/hypopnea a systematic review and meta-analysis. *Chest*. 2014;145:762–771. doi: 10.1378/chest.13-1115.
168. Muxfeldt ES, Margallo V, Costa LM, Guimarães G, Cavalcante AH, Azevedo JC, de Souza F, Cardoso CR, Salles GF. Effects of continuous positive airway pressure treatment on clinic and ambulatory blood pressures in patients with obstructive sleep apnea and resistant hypertension: a randomized controlled trial. *Hypertension*. 2015;65:736–742. doi: 10.1161/HYPERTENSIONAHA.114.04852.
169. Mendelson M, Vivodtzev I, Tamisier R, Laplaud D, Dias-Domingos S, Baguet JP, Moreau L, Koltes C, Chavez L, De Lamberterie G, Herengt F, Levy P, Flore P, Pépin JL. CPAP treatment supported by telemedicine does not improve blood pressure in high cardiovascular risk OSA patients: a randomized, controlled trial. *Sleep*. 2014;37:1863–1870. doi: 10.5665/sleep.4186.
170. Chirinos JA, Gurubhagavatula I, Teff K, Rader DJ, Wadden TA, Townsend R, Foster GD, Maislin G, Saif H, Broderick P, Chittams J, Hanlon AL, Pack AI. CPAP, weight loss, or both for obstructive sleep apnea. *N Engl J Med*. 2014;370:2265–2275. doi: 10.1056/NEJMoa1306187.
171. McMillan A, Bratton DJ, Faria R, Laskawiec-Szkonter M, Griffin S, Davies RJ, Nunn AJ, Stradling JR, Riha RL, Morrell MJ; PREDICT Investigators. Continuous positive airway pressure in older people with obstructive sleep apnoea syndrome (PREDICT): a 12-month, multicentre, randomised trial. *Lancet Respir Med*. 2014;2:804–812. doi: 10.1016/S2213-2600(14)70172-9.
172. Sivam S, Witting PK, Hoyos CM, Maw AM, Yee BJ, Grunstein RR, Phillips CL. Effects of 8 weeks of CPAP on lipid-based oxidative markers in obstructive sleep apnea: a randomized trial. *J Sleep Res*. 2015;24:339–345. doi: 10.1111/jsr.12271.
173. Centers for Disease Control and Prevention. *CDC Health Disparities and Inequalities Report–United States*, Atlanta, GA: Centers for Disease Control and Prevention; 2011.
174. Chang VW, Lauderdale DS. Income disparities in body mass index and obesity in the United States, 1971-2002. *Arch Intern Med*. 2005;165:2122–2128. doi: 10.1001/archinte.165.18.2122.
175. Freedman DS; Centers for Disease Control and Prevention (CDC). Obesity–United States, 1988–2008. *MMWR Suppl*. 2011;60:73–77.
176. May AL, Freedman D, Sherry B, Blanck HM, Centers for Disease Control and Prevention (CDC). Obesity–United States, 1999–2010. *MMWR Suppl*. 2013;62:120–128.
177. Hertz RP, Unger AN, Cornell JA, Saunders E. Racial disparities in hypertension prevalence, awareness, and management. *Arch Intern Med*. 2005;165:2098–2104. doi: 10.1001/archinte.165.18.2098.

178. Keenan NL, Rosendorf KA; Centers for Disease Control and Prevention (CDC). Prevalence of hypertension and controlled hypertension–United States, 2005-2008. *MMWR Suppl*. 2011;60:94–97.
179. Beckles GL, Zhu J, Moonesinghe R; Centers for Disease Control and Prevention (CDC). Diabetes–United States, 2004 and 2008. *MMWR Suppl*. 2011;60:90–93.
180. Hale L. Who has time to sleep? *J Public Health (Oxf)*. 2005;27:205–211. doi: 10.1093/pubmed/fdi004.
181. Hale L, Do DP. Sleep and the inner city: how race and neighborhood context relate to sleep duration. Paper presented at: Population Association of America Annual Meeting; March 30–April 1, 2006; Los Angeles, CA.
182. Hale L, Do DP. Racial differences in self-reports of sleep duration in a population-based study. *Sleep*. 2007;30:1096–1103.
183. Ruiter ME, Decoster J, Jacobs L, Lichstein KL. Normal sleep in African-Americans and Caucasian-Americans: a meta-analysis. *Sleep Med*. 2011;12:209–214. doi: 10.1016/j.sleep.2010.12.010.
184. Whinnery J, Jackson N, Rattanaumpawan P, Grandner MA. Short and long sleep duration associated with race/ethnicity, sociodemographics, and socioeconomic position. *Sleep*. 2014;37:601–611. doi: 10.5665/sleep.3508.
185. Lauderdale DS, Knutson KL, Yan LL, Rathouz PJ, Hulley SB, Sidney S, Liu K. Objectively measured sleep characteristics among early-middle-aged adults: the CARDIA study. *Am J Epidemiol*. 2006;164:5–16. doi: 10.1093/aje/kwj199.
186. Grandner MA, Petrov ME, Rattanaumpawan P, Jackson N, Platt A, Patel NP. Sleep symptoms, race/ethnicity, and socioeconomic position. *J Clin Sleep Med*. 2013;9:897–905; 905A–905D. doi: 10.5664/jcsm.2990.
187. Ruiter ME, DeCoster J, Jacobs L, Lichstein KL. Sleep disorders in African Americans and Caucasian Americans: a meta-analysis. *Behav Sleep Med*. 2010;8:246–259. doi: 10.1080/15402002.2010.509251.
188. Grandner MA, Williams NJ, Knutson KL, Roberts D, Jean-Louis G. Sleep disparity, race/ethnicity, and socioeconomic position. *Sleep Med*. 2016;18:7–18. doi: 10.1016/j.sleep.2015.01.020.
189. Patel NP, Grandner MA, Xie D, Branas CC, Gooneratne N. "Sleep disparity" in the population: poor sleep quality is strongly associated with poverty and ethnicity. *BMC Public Health*. 2010;10:475. doi: 10.1186/1471-2458-10-475.
190. Grandner MA, Hale L, Moore M, Patel NP. Mortality associated with short sleep duration: the evidence, the possible mechanisms, and the future. *Sleep Med Rev*. 2010;14:191–203. doi: 10.1016/j.smrv.2009.07.006.
191. Watson NF, Badr MS, Belenky G, Bliwise DL, Buxton OM, Buysse D, Dinges DF, Gangwisch J, Grandner MA, Kushida C, Malhotra RK, Martin JL, Patel SR, Quan SF, Tasali E. Recommended amount of sleep for a healthy adult: a joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society. *Sleep*. 2015;38:843–844. doi: 10.5665/sleep.4716.
192. Grandner MA, Buxton OM, Jackson N, Sands-Lincoln M, Pandey A, Jean-Louis G. Extreme sleep durations and increased C-reactive protein: effects of sex and ethnoracial group. *Sleep*. 2013;36:769–779E. doi: 10.5665/sleep.2646.
193. Grandner MA, Hale L, Jackson N, Patel NP, Gooneratne NS, Troxel WM. Perceived racial discrimination as an independent predictor of sleep disturbance and daytime fatigue. *Behav Sleep Med*. 2012;10:235–249. doi: 10.1080/15402002.2012.654548.
194. Hicken MT, Lee H, Ailshire J, Burgard SA, Williams DR. "Every shut eye, ain't sleep": the role of racism-related vigilance in racial/ethnic disparities in sleep difficulty. *Race Soc Probl*. 2013;5:100–112. doi: 10.1007/s12552-013-9095-9.
195. Steffen PR, Bowden M. Sleep disturbance mediates the relationship between perceived racism and depressive symptoms. *Ethn Dis*. 2006;16:16–21.
196. Thomas KS, Bardwell WA, Ancoli-Israel S, Dimsdale JE. The toll of ethnic discrimination on sleep architecture and fatigue. *Health Psychol*. 2006;25:635–642. doi: 10.1037/0278-6133.25.5.635.
197. Tomfohr L, Pung MA, Edwards KM, Dimsdale JE. Racial differences in sleep architecture: the role of ethnic discrimination. *Biol Psychol*. 2012;89:34–38. doi: 10.1016/j.biopsycho.2011.09.002.
198. Williams DR. Race, socioeconomic status, and health: the added effects of racism and discrimination. *Ann NY Acad Sci*. 1999;896:173–188.
199. Tomfohr LM, Ancoli-Israel S, Dimsdale JE. Childhood socioeconomic status and race are associated with adult sleep. *Behav Sleep Med*. 2010;8:219–230. doi: 10.1080/15402002.2010.509236.