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Sleep Symptoms Associated with Intake of Specific Dietary Nutrients

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Abstract

Sleep symptoms are associated with weight gain and cardiometabolic disease. The potential role of diet has been largely unexplored. Data from the 2007–2008 NHANES were used (N=4,552) to determine which nutrients were associated with sleep symptoms in a nationally-representative sample. Survey items assessed difficulty falling asleep, sleep maintenance difficulties, non-restorative sleep, and daytime sleepiness. Analyses were adjusted for energy intake, other dietary factors, exercise, BMI and sociodemographics. Population-weighted, logistic regression, with backwards-stepwise selection, examined which nutrients were associated with sleep symptoms. Odds ratios (ORs) reflect the difference in odds of sleep symptoms associated with a doubling in nutrient. Nutrients that were independently associated with difficulty falling asleep included (in order): Alpha-Carotene (OR=0.96), Selenium (OR=0.80), Dodecanoic Acid (OR=0.91), Calcium (OR=0.83), and Hexadecanoic Acid (OR=1.10). Nutrients that were independently associated with sleep maintenance difficulties included: Salt (OR=1.19), Butanoic Acid (0,81), Carbohydrate (OR=0.71), Dodecanoic Acid (OR=0.90), Vitamin D (OR=0.84),, Lycopene (OR=0.98), Hexanoic Acid (OR= 1.25), and Moisture (OR=1.27). Nutrients that were independently associated with non-restorative sleep included Butanoic Acid (OR=1.09), Calcium (OR=0.81), Vitamin C (OR=0.92), Water (OR=0.98), Moisture (OR= 1.41), and Cholesterol (OR= 1.10). Nutrients that were independently associated with sleepiness included: Moisture (OR=1.20), Theobromine (OR=1.04), Potassium (OR= 0.70), Water (OR=0.97). These results suggest novel associations between sleep symptoms and diet/metabolism, potentially explaining associations between sleep and cardiometabolic diseases.

Keywords

Sleep; Diet; Nutrition; Insomnia; Epidemiology

INTRODUCTION

Sleep disorders, including insomnia and obstructive sleep apnea, are major public health issues that affect millions of Americans. Because sleep disorders can impair quality of life, increase risk of other diseases, and result in an economic burden estimated to be tens of billions of dollars annually for both sleep apnea (Potts et al., 2013) and insomnia (Kessler et al., 2011), the consequences and causes of reduced sleep quality are important to identify.

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Experimental studies that restricted time available for sleep found changes in appetite regulating hormones, specifically lower levels of leptin (a satiety signal) and higher levels of ghrelin (an appetite stimulant) compared to extended time in bed.. This suggests that sleep loss may be associated with alterations in diet. For that reason, other experimental studies examined whether sleep restriction impacted dietary behavior. For example, 6 nights of time in bed restricted to 4 hours in men and women aged 30–45 years was associated with a significant increase in caloric intake, particularly from fat, without a compensatory change in energy expenditure.(St-Onge et al., 2011) Another study restricted time in bed to 5 hours for 5 days and observed increased food intake compared to 9 hours in bed (Markwald et al., 2013). This study also observed a slight increase in energy expenditure after sleep restriction, however it was not equivalent to the increase in energy intake and therefore there was significant weight gain as well. A third study examined the effect of sleep restriction that was 2/3 of their habitual time in bed, thereby accounting for individual differences in habitual sleep times (Calvin et al., 2013). This study also observed an increase in caloric intake after sleep restriction without any change in energy expenditure. The effects of all 3 studies were observed with just a few nights of sleep restriction, but if these effects became chronic, it would lead to weight gain. Experimental studies that impaired sleep quality and assessed food intake have not yet been published, however, sleep disturbances are associated with sleep loss. Thus effects of sleep restriction may also be observed when sleep quality is impaired as well. Since alterations in dietary composition have been shown to increase obesity risk, this possibility has important implications for the millions who suffer from sleep disorders such as insomnia and obstructive sleep apnea.(Mozaffarian et al., 2011)

Experimental studies are conducted in controlled, artificial environments for only a short period of time, and therefore it is important to determine whether the association between sleep and diet persist outside the laboratory. Only a few observational studies have examined whether there is an association between habitual sleep patterns and diet, but most of these focused on sleep duration (Grandner et al., 2010, Nishiura et al., 2010). A study of adults in India found that participants with symptoms of insomnia had a lower total caloric intake, lower protein intake and lower carbohydrate intake compared to normal sleepers (Zadeh and Begum, 2011). However, when examining the dietary proportions of macronutrients, the proportion of carbohydrate intake was slightly higher and the proportion of fat was slightly lower in the presence of insomnia.(Zadeh and Begum, 2011) Among young female students in Japan, women with healthier sleep habits (including better sleep quality) were significantly more likely to eat breakfast regularly (Nakade et al., 2009), a dietary behavior associated with better cardiometabolic health (Mekary et al., 2012, Alexander et al., 2009, Smith et al., 2010). In a study of women, shorter sleep duration measured using actigraphy (and, to a lesser extent, sleep diary) was associated with a higher consumption of fat and nutrients whose primary sources are high-fat foods, even after adjustment for demographics, socioeconomics, total energy intake, BMI and exercise (Grandner et al., 2010). Results from these few observational studies suggest a relationship between sleep patterns and feeding behavior may exist, but additional studies are necessary to determine the nature of these associations at the population-level.

The goal of the present analyses was to determine whether an association between self-reported sleep quality and dietary factors was present in a large, nationally representative study in the US. The National Health and Nutrition Examination Survey (NHANES) provided a unique opportunity to examine these cross-sectional associations in a large sample of adults 18 years of age and older. In addition to data on macronutrient composition, NHANES has detailed information on micronutrients and other dietary behaviors, allowing for the assessment of associations between sleep, diet and nutrition in a large population. Given the sparse literature on the relationships between sleep and both macro- and micro-nutrients, cross-sectional associations will provide novel information

about intake of different nutrients that are associated with sleep disturbances, which may help to generate specific hypotheses for future studies.

METHODS

Data Source

The subjects used in this study were participants in the 2007–2008 National Health and Nutrition Examination Survey (NHANES), a national survey conducted by the Centers for Disease Control and Prevention, reporting the health and nutritional characteristics of children and adults. Participants were administered questionnaires assessing their demographic, socioeconomic, nutritional, and related statuses during in-person interviews conducted in the home. Additionally, physical examinations were performed in mobile medical facilities to collect medical and physiological data; additional laboratory tests were also performed from blood and urine samples collected on-site. In order to compensate for under-representation, African Americans, Hispanics, and adults over 60 were over-sampled.

Sampling in this survey was performed to ensure generalizability to the entire population across all ages. Because of the complexity of the survey design coupled with variable probabilities of selection, the data used in the following analyses were also weighted to control for representativeness by following the procedures outlined in the current NHANES Analytic and Reporting Guidelines (2006). For the present study, analyses included adults aged 18 years and older with complete data on all independent and dependent variables (n=4,548).

Measures

Sleep Symptoms—Sleep symptoms included difficulty falling asleep, difficulty maintaining sleep, non-restorative sleep and daytime sleepiness. These represent hallmark symptoms of a number of sleep disorders, including the most prevalent (e.g., insomnia and obstructive sleep apnea). Difficulty falling asleep was assessed with the question, “In the past month, how often did you have trouble falling asleep?” Difficulty maintaining sleep was assessed with the question, “In the past month, how often did you wake up during the night and had trouble getting back to sleep?” Non-restorative sleep was assessed with the question, “In the past month, how often did you feel unrested during the day, no matter how many hours of sleep you had?” Daytime sleepiness was assessed using the question, “In the past month, how often did you feel excessively or overly sleepy during the day?” Responses were categorized as 0, 1 time a month, 2–4 times a month, 5–15 times a month, and 16–30 times a month.

Diet and Nutrition—Diet and nutrition data were collected as part of standard NHANES procedures (Centers for Disease Control and Prevention, 2008). This consisted of 24-hour recall, guided by a structured interview (day 1 data). Bean bags, measuring cups, rulers and other guides were used to aid in determining amounts and assisting subject recall. Dietary nutrient information was based on established values and parameters (Raper et al., 2004, Moshfegh et al., 2008, Rumpler et al., 2008). A validated 24-hour recall is generally considered sufficient to generalize to overall eating patterns at the population level (Dary and Imhoff-Kunsch, 2012). The dietary interview component of NHANES is conducted as a partnership between the U.S. Department of Agriculture (USDA) and the U.S. Department of Health and Human Services (DHHS). Under this partnership, DHHS’ National Center for Health Statistics (NCHS) is responsible for the sample design and data collection and USDA’s Food Surveys Research Group is responsible for the dietary data collection methodology, maintenance of the databases used to code and process the data, and data review and processing. The 24-hour recall method has been rigorously validated (Raper et

al., 2004, Moshfegh et al., 2008, Rumpler et al., 2008). Variables included in the present analysis included assessments of overall diet, macronutrients, and micronutrients, including fats, proteins, vitamins, minerals, salt, water, and other substances. For a complete list, see Supplementary Materials ("Dietary Variables Assessed").

Sociodemographic, Socioeconomic, and Health Covariates—A number of potential confounders were assessed. These included age, sex, race/ethnicity (Non-Hispanic White, Hispanic/Latino, Black/African-American, and Asian/Other), education (less than high school, high school graduate, some college, and college graduate), household income (<$20,000, $20-$25,000, $25-$35,000, $35-$45,000, $45-$55,000, $55-$65,000, $65-$75,000, and >$75,000), minutes of exercise per day, and objectively-measured body mass index (BMI). Depression was measured with, "Over the last 2 weeks, how often have you been bothered by ... feeling down, depressed, or hopeless?" Responses were recorded as "Not at all," "Several days," "More than half the days," and "Nearly every day." These variables were specifically chosen *a priori* because of their potential associations with both sleep symptoms and dietary behavior and they were used in the one previous study of dietary nutrients and sleep duration (Grandner et al., 2010).

Statistical Analyses

Differences in dietary and demographic variables between sleep groups were assessed using independent T-Tests for continuous variables and Pearson Chi-square for categorical variables.

We used ordinal logistic regression models with each sleep symptom as the dependent variable. Although it may be argued that sleep symptoms may cause changes in certain dietary behaviors, the nature of cross-sectional data does not allow for determination of causation. Thus, we can only test for associations and having the sleep symptoms as the dependent variables substantially reduces the number of regression models providing the most parsimonious analysis. Therefore, the effects of diet on the presence sleep symptoms were assessed using ordinal logistic regression. Separate regression models were estimated for each dietary factor and nutrient. Finally, to examine the most parsimonious model explaining each sleep symptom, a backward stepwise selection procedure was implemented with demographic, depression, nutrient intake, and special diet variables including alcohol intake forced into each model. Additional variables were then selected based upon an inclusion significance criterion of 0.05 and exclusion criterion of 0.10. These variables are considered to contribute unique variance to the model and will be presented in order of the amount of variance they explain. To avoid model selection bias due to collinearity, dietary variables that were correlated above rho=0.75 were excluded from the variable list in the model selection procedure (when variables were collinear, the variable with the highest correlation with the sleep item was retained).

All continuous dietary variables were log-transformed for analysis.. Values represent odds associated with a 100% increase in intake for continuous variables, with the exception of Fatty Acids, which were expressed in standardized units, such that their effects are reported in terms of their standard deviations. Analyses were appropriately weighted for representativeness in accordance with NHANES 2007–2008 weighting guidelines. Because of the number of hypotheses being tested, P values were Benjamini–Hochberg corrected for false discovery rate.(Benjamini and Hochberg, 1995) This allows us to maintain an alpha level of 0.05 for analyses.

RESULTS

Sample Characteristics

Characteristics of the sample are reported in Table 1. All cases were weighted, resulting in a sample that was closely matched to the general population. Sleep symptoms were, however, differentially distributed across sociodemographic, socioeconomic, and health variables, justifying their inclusion as covariates. Those with difficulty falling asleep or difficulty maintaining sleep were more likely to be female, Non-Hispanic White, have less education, earn less income and report greater depressive symptoms. Those with non-restorative sleep and daytime sleepiness were more likely to be younger, female, Non-Hispanic White, have lower income and greater depressive symptoms. Non-restorative sleep varied significantly by educational level but not in a linear fashion. In addition, daytime sleepiness was associated with higher BMI.

Overview of Reported Results

The results presented below are categorized based on the complexity of the analysis. First, results of unadjusted, simple comparisons using ANOVA are reported (Supplementary Tables 1A-1D). Second, unadjusted and adjusted ordinal logistic regression results for overall diet are reported (Supplementary Table 2). Third, unadjusted and adjusted ordinal logistic regression results for specific macronutrients and micronutrients are presented (Supplementary Tables 3A-3D). Fourth, the stepwise regression results are presented in Tables 2–5. While the ordinal regression results presented in Supplementary Table 3 consider each nutrient in a separate model (ignoring inter-correlations among nutrients), the stepwise results report on ordinal regression analyses that account for the overlap among nutrients. Therefore, although the other analyses are relevant, the stepwise results are considered the principal findings.

Group Differences in Dietary Variables

Results of bivariate analyses (F tests for continuous and X^2 for categorical variables) are reported in Supplementary Table 1, which describes differences according to difficulty falling asleep (1A), differences according to difficulty maintaining sleep (1B), differences according to non-restorative sleep (1C), and differences according to daytime sleepiness (1D). See supplementary materials for written interpretations of these data. Overall, dietary pattern differences were seen more for difficulty falling asleep and difficulty maintaining sleep than the other two sleep symptoms.

Results from Multivariable Regression Analyses of Overall Diet

Results from unadjusted and adjusted analyses are reported in Supplementary Table 2. In unadjusted analyses, difficulty maintaining sleep was associated with lower food variety, higher likelihood of less food reported vs. usual intake, and being on a special diet. After adjustment for covariates, these were not significant. Non-restorative sleep was associated with lower likelihood of being on a low fat/cholesterol diet in both unadjusted and adjusted analyses. Daytime sleepiness was associated with increased caloric intake in adjusted analyses. It was also associated with higher likelihood of less food reported compared to usual diet in unadjusted analyses only, and being on a low fat/cholesterol diet in both unadjusted and adjusted analyses.

Results from Multivariable Regression Analyses of Specific Nutrient Variables

Results from multivariable regression analyses are reported in Supplementary Table 3 for difficulty falling asleep (3A), difficulty maintaining sleep (3B), non-restorative sleep (3C)

and daytime sleepiness (3D). See Supplementary Information for interpretations of these results.

Results From Stepwise Regression Analyses

Results from the stepwise regression for difficulty falling asleep are reported in Table 2. After all sociodemographic, socioeconomic, health and dietary covariates were forced into the model, the nutrient variables that were significantly associated with greater difficulty falling asleep were, in order, less alpha carotene, less selenium, less dodecanoic acid, less calcium, and more hexadecanoic acid. The nutrients that were significantly associated with greater difficulty maintaining asleep (Table 3), in order, were more salt use, less butanoic acid, less carbohydrate, less dodecanoic acid, less vitamin D, less lycopene, more hexanoic acid, and more moisture. For non-restorative sleep (Table 4), the nutrients that explained the most unique variance were, in order, more butanoic acid, less calcium, less vitamin C, less plain water, more moisture, and more cholesterol. Finally, the nutrients that were significantly associated with greater daytime sleepiness (Table 5) were, in order, more moisture, more theobromine, less potassium, and less plain water.

DISCUSSION

Results from these nationally representative data indicate that sleep symptoms are associated with some dietary components. Overall diet was significantly associated with sleep symptoms. Difficulty maintaining sleep was associated with fewer foods in the diet and, along with daytime sleepiness, was associated with being on a special diet. Being on a low fat/cholesterol diet was associated with less non-restorative sleep and daytime sleepiness.

Several of the specific nutrients were associated with sleep symptoms as well. Many of these nutrients are associated with health, as will be described, and therefore may have implications for associations between sleep disturbances and disease risk. Reduced selenium intake was associated with difficulty falling asleep. Selenium is found in meats, seafood, dairy products, grains and nuts and is an essential micronutrient that plays an important role in initiating and enhancing immunity as well as in immunoregulation, which is crucial for preventing excessive responses that could lead to chronic inflammation (Huang et al., 2011). Less Vitamin C intake was associated with non-restorative sleep. Vitamin C, which is found in high concentrations in fruit and vegetables, is an antioxidant,(Hermsdorff et al., 2011) which could protect against the development of cardiovascular disease and cancer.

Calcium intake was associated with decreased difficulty falling asleep and non-restorative sleep. Although published evidence linking dietary calcium (or calcium supplementation) with insomnia symptoms, fewer sleep difficulties associated with increased calcium may have been a result on effects of calcium on lowering blood pressure(Liebman et al., 1986). Theobromine was found to be associated with daytime sleepiness. This is somewhat in conflict with a previous report from this sample associating theobromine with lower likelihood of long sleep duration (Grandner et al., 2013), which is associated with increased daytime sleepiness (Grandner and Kripke, 2004). Since theobromine may have stimulant qualities (Benton, 2004) and is frequently found in products containing caffeine, this may reflect increased consumption of foods or drinks that may function as stimulants by those with daytime sleepiness (though it should be noted that there were no significant findings for caffeine in this sample). Vitamin D was associated with less difficulty maintaining sleep. Although research on sleep effects of vitamin D is scarce, previous research has shown that dietary vitamin D was associated with later sleep timing and increased subjective napping in postmenopausal women (Grandner et al., 2010). Lycopene, an antioxidant with effects on cell differentiation and growth (Palozza et al., 2011), was also associated with less difficulty falling asleep. In a previous study in this sample, very short sleepers were found to have

consumed less lycopene than 7–8 hour sleepers (Grandner et al., 2013). Potassium was associated with less daytime sleepiness. One previous study found that potassium was associated with earlier sleep timing (Sato-Mito et al., 2011), though if there is a common mechanism, it is unknown. The finding that salt use was associated with impaired sleep is the opposite of what was reported in a previous study that found that restricted sodium intake caused sleep disruption (Vitiello et al., 1983).

The present study found that more total moisture was associated with difficulty maintaining sleep, non-restorative sleep, and daytime sleepiness, but that more total plain water consumed was associated with less non-restorative sleep and daytime sleepiness. In this context, data from this same sample showed that greater water intake was associated with less likelihood of very short or short sleep duration (Grandner et al., 2013), and a previous study found that water was associated with greater actigraphic sleep time and fewer subjective naps (Grandner et al., 2010). The difference between these variables is that water intake was specific to water itself, and total moisture refers to the total moisture content of all foods and beverages (e.g., watermelon, lettuce, coffee). These results suggest that drinking more water, which is a behavior associated with a number of health benefits (Muckelbauer et al., 2009), may also be associated with healthy sleep, but that total moisture consumption may have some negative effects on sleep, perhaps due to fragmentation caused by more frequent sensations regarding urination (Ancoli-Israel et al., 2011).

Difficulty falling asleep was associated with greater intake of hexadecanoic acid, a saturated fat, whereas it was associated with less intake of dodecanoic acid, a monounsaturated fat. Difficulty maintaining sleep was also associated with less intake of both dodecanoic acid and butanoic acid and greater intake of hexanoic acid. Hexanoic acid (6:0), also known as caproic acid, is found in coconut oil and in goat and cow butter. Butanoic acid (4:0), also known as butyric acid, conversely, was found to be associated with a decreased likelihood of difficulty maintaining sleep. Butyric acid is found in cow milk, and has been implicated in reducing risk of colon cancer (Parodi, 1997). Hexadecanoic acid (16:0), also known as palmitic acid, is found in butter, cheese, milk, and meat. One study reported rats that were fed high-fat diets enriched in palmitic acid, showed an impairment of the ability of leptin and insulin to regulate food intake and body weight compared to animals fed a high-fat unsaturated-enriched diet or low-fat diet (Benoit et al., 2009 PMID: 19726875). Interestingly, reduced intake of dodecanoic acid was associated with both difficulties falling asleep and maintaining sleep, perhaps suggesting that diets deficient in this fatty-acid may contribute to etiology of insomnia symptoms. Dodecanoic acid, also known as lauric acid, is a 12-carbon chain saturated fatty acid that is enriched in coconut oil. Lauric acid has been shown to increase serum high-density lipoprotein cholesterol when added to the diet without affecting low-density lipoprotein levels, compared to *trans*-fatty acids derived from partially hydrogenated soybean oil (de Roos et al., 2001). A previous study in this same sample found that dodecanoic acid was associated with decreased likelihood of long sleep duration (Grandner et al., 2013). Perhaps diets enriched with this saturated fatty acid may not only reduce the ratio of LDL/HDL levels, which in turn is associated with healthy cardiovascular function, but may also be associated with healthier sleep. Notably, cholesterol intake was associated with non-restorative sleep in this sample and was associated with shorter actigraphic sleep duration and sleep efficiency and subjective napping in a study of postmenopausal women (Grandner et al., 2010). Since dodecanoic acid has been shown to increase high-density lipoprotein (“good”) cholesterol more than any other fatty acid (Mensink et al., 2003 PMID:12716665), future studies examining the role of diets containing this fatty-acid on “good” versus “bad” cholesterol levels will be needed to further clarify our observed associations and determine whether causality exists between dietary intake of these fatty-acids and various health outcomes, including cardiovascular function and sleep quality.

Only a few other studies have examined associations between diet and indicators of sleep quality. Among young adults in India, symptoms of insomnia, which included difficulty falling asleep, difficulty maintaining sleep, early awakening and sleep duration ≤6 hours and non-restorative sleep, were associated with a lower caloric intake (Zadeh and Begum, 2011). This is similar to our finding that those with difficulty falling asleep consumed fewer calories (Supplementary Table 1A). However, this is dissimilar to our regression results that showed a general positive relationship between caloric intake and sleep symptoms (Supplementary Table 2). It should be noted that the study in India did not adjust for covariates. In a study of almost 10,000 older French adults (≥65 years), the Mediterranean diet (based on 11 dietary components) was associated with reduced odds of insomnia symptoms, including difficulty falling asleep and difficulty maintaining sleep in women (Jaussent et al., 2011). These two studies were also cross-sectional, so it is not clear whether insomnia symptoms somehow determine dietary choices or if caloric intake or the dietary components of a Mediterranean diet effect insomnia symptoms.

The strengths of this paper include the large sample size, nationally representative data and detailed identification of dietary components. There are, however, some limitations to acknowledge. The self-reported sleep symptoms are non-specific and could reflect a variety of underlying causes, including certain sleep disorders such as insomnia or sleep disordered breathing. Furthermore, these are cross-sectional data so we cannot determine if the sleep disturbances can result in alterations in diet or if certain dietary components can impair sleep. With respect to sleep disturbances impacting diet, experimental studies of sleep restriction (discussed above) observed effects on appetite regulation, but similar experimental studies of sleep disturbances have not been published. In support of the latter casual direction, dietary supplements have actually been tested as a treatment for insomnia, including tart cherry juice,(Pigeon et al., 2010) melatonin, magnesium, and zinc,(Rondanelli et al., 2011) and valerian,(Taibi et al., 2007) albeit with only limited to moderate success. Certainly, caffeine is likely part of a vicious cycle of poor sleep leading to increased caffeine consumption, which in turn promotes impaired sleep. Also, data on timing of meals is not available. Another limitation is related to the challenge of measuring dietary intake. Assessments of food intake over an arbitrary 24-hour period are prone to a number of biases. Some of these biases are partially addressed by including covariates (such as similarity to a typical day), but they cannot be completely accounted for. In this context, we recognize that all methods of assessing habitual diet are imperfect. Although the methods employed for the current study are well-validated for population-level assessments, they are not well-validated for individual assessments. Thus, the results should be interpreted with appropriate caution.

Finally, we did not adjust for supplement intakes in these analyses. Many Americans do take various supplements, however, we did not include supplement data for several reasons. First, since supplements in the US are not regulated the listed ingredients are unreliable. The amount of specific ingredients may vary by supplement, brand and batch. Second, since supplements can provide substantial amounts of certain nutrients that are very difficult to obtain from dietary sources, associates between sleep and dietary data may be skewed. For example, if the of amount of such nutrients contained in supplements exceeds the typical range of dietary intake by a wide margin, then nutrients from supplements would have a high degree of influence over the statistical results and would therefore render the results unreliable. Third, recall of supplement intake was not performed in the same way as recall of diet. Adding this dimension would compound existing measurement error. Based on this reasoning, supplement data were not included."

The potential link between sleep quality and dietary nutrients has important implications for health. If increased consumption or deficiency of certain nutrients can impair sleep, this would increase the risk of developing insomnia, which is associated with reduced quality of

life, increased work absenteeism and reduced productivity.(Leger and Bayon, 2010) Alternatively, if disturbed sleep, as observed in insomnia and sleep apnea, can impact dietary choices then this association may partly explain cardiometabolic health problems associated with these sleep disorders. Indeed, sleep disturbances have been linked with impairments in glucose metabolism and increased diabetes risk.(Knutson et al., 2011) The results of these analyses warrant future research to examine the association between sleep disturbances and dietary choices in greater detail using a longitudinal design, and to conduct experimental studies to determine if these nutrients impair sleep.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Table 1

Subject characteristics by sleep symptoms

Variable	Category	Total Sample	Difficulty Falling Asleep						Difficulty Maintaining Sleep					
			Almost Always	Often	Sometimes	Rarely	Never	P	Almost Always	Often	Sometimes	Rarely	Never	P
N (%)		4548	363 (8%)	463 (10%)	966 (21%)	888 (20%)	1,868 (41%)		362 (8%)	565 (12%)	1,095 (24%)	848 (19%)	1,678 (37%)	
Age	Mean (SD)	46.3 (16.5)	46.7 (14.9)	44.6 (14.8)	46.8 (16.6)	47.4 (15.6)	45.8 (17.8)	0.09	48.5 (14.6)	46.7 (15.4)	47.8 (16.2)	46.5 (16.0)	44.5 (17.7)	<0.01
Sex	Female	53.1%	67.90%	63.90%	55.17%	49.47%	47.28%	<0.01	66.55%	62.05%	58.89%	46.48%	46.09%	<0.01
	Male	46.9%	32.10%	36.10%	44.83%	50.53%	52.72%		33.45%	37.95%	41.11%	53.52%	53.91%	
Race/Ethnicity	Non-Hispanic White	71.6%	72.80%	79.87%	72.19%	76.55%	65.36%	<0.01	76.10%	78.25%	71.68%	74.31%	66.28%	<0.01
	Hispanic/Latino	13.0%	11.02%	8.84%	12.09%	10.74%	16.74%		10.26%	8.57%	12.04%	12.80%	16.27%	
	Black/African American	10.9%	11.31%	8.30%	10.10%	7.45%	14.06%		9.71%	10.25%	9.77%	9.17%	13.17%	
	Asian/Other	4.5%	4.87%	2.99%	5.62%	5.27%	3.83%		3.93%	2.93%	6.51%	3.72%	4.29%	
Education	Less Than High School	25.5%	25.24%	17.52%	15.94%	15.20%	22.25%	<0.01	22.39%	18.80%	18.50%	13.59%	21.84%	<0.01
	High School Graduate	19.0%	30.02%	24.68%	23.60%	24.05%	26.43%		33.80%	23.84%	25.77%	23.44%	24.81%	
	Some College	25.4%	30.80%	34.76%	34.50%	28.79%	26.45%		27.49%	34.32%	28.53%	32.14%	28.97%	
	College Graduate	30.1%	13.93%	23.04%	25.96%	31.96%	24.87%		16.33%	23.04%	27.19%	30.83%	24.38%	
Income	<20k	33.0%	30.57%	17.35%	16.58%	11.52%	14.70%	<0.01	25.40%	19.15%	15.22%	11.85%	15.70%	0.02
	20–25k	16.1%	7.37%	5.51%	7.28%	7.34%	7.49%		6.05%	6.91%	7.33%	5.48%	8.41%	
	25–35k	7.2%	13.51%	11.44%	12.59%	9.75%	12.39%		12.41%	13.68%	12.69%	9.84%	11.56%	
	35–45k	11.9%	6.46%	6.66%	9.09%	10.46%	9.07%		8.43%	7.10%	8.20%	10.61%	9.19%	
	45–55k	8.9%	7.04%	10.93%	8.53%	9.16%	7.23%		7.23%	8.58%	9.33%	7.60%	8.20%	
	55–65k	8.3%	5.10%	9.64%	4.87%	7.15%	7.97%		6.55%	5.14%	7.39%	6.82%	7.77%	
	65–75k	7.1%	8.19%	7.36%	7.36%	8.02%	7.43%		7.39%	8.31%	7.88%	6.30%	7.91%	
	>75k	7.6%	21.75%	31.12%	33.69%	36.60%	33.70%		26.54%	31.13%	31.96%	41.50%	31.25%	
Minutes of Exercise	Mean (SD)	166 (223)	161 (207)	167 (215)	163 (211)	169 (204)	168 (248)	0.99	165 (216)	186 (244)	155 (203)	162 (204)	170 (241)	0.41
Body Mass Index	Mean (SD)	28.7 (6.8)	29.5 (7.7)	29.0 (6.4)	28.2 (6.3)	28.4 (5.8)	29.0 (7.5)	0.06	29.6 (7.4)	28.7 (6.9)	28.6 (6.2)	28.3 (6.3)	28.8 (7.3)	0.36

Variable	Category	Total Sample	Difficulty Falling Asleep						Difficulty Maintaining Sleep					
			Almost Always	Often	Sometimes	Rarely	Never	P	Almost Always	Often	Sometimes	Rarely	Never	P
N (%)		**4548**	**363 (8%)**	**463 (10%)**	**966 (21%)**	**888 (20%)**	**1,868 (41%)**		**362 (8%)**	**565 (12%)**	**1,095 (24%)**	**848 (19%)**	**1,678 (37%)**	
Depression	Not at All	75.9%	48.57%	59.29%	72.40%	81.69%	86.16%	<0.01	52.58%	63.46%	71.99%	84.06%	84.49%	<0.01
	Several Days	17.5%	32.82%	30.07%	20.75%	13.94%	10.21%		30.53%	26.53%	20.85%	12.73%	11.26%	
	Nearly Half the Days	3.5%	6.57%	4.80%	4.61%	3.29%	1.91%		6.39%	4.89%	4.13%	2.35%	2.57%	
	All the Time	3.0%	12.03%	5.84%	2.24%	1.08%	1.71%		10.50%	5.12%	3.04%	0.86%	1.67%	
N (%)		4548	462 (10%)	687 (15%)	1,201 (26%)	703 (16%)	1,495 (33%)		272 (6%)	525 (12%)	1,191 (26%)	908 (20%)	1,652 (36%)	
Age	Mean (SD)	46.3 (16.5)	44.5 (14.9)	42.6 (14.0)	44.8 (14.9)	48.3 (16.2)	50.1 (19.9)	<0.01	44.2 (15.7)	43.3 (14.7)	45.2 (15.7)	46.6 (15.1)	48.8 (18.8)	<0.01
Sex	Female	53.1%	65.8%	58.3%	55.0%	45.4%	46.9%	<0.01	57.98%	64.9%	51.6%	53.6%	48.2%	<0.01
	Male	46.9%	34.2%	41.8%	45.0%	54.6%	53.1%		42.0%	35.1%	48.5%	46.4%	51.8%	
Race/Ethnicity	Non-Hispanic White	71.6%	76.6%	78.1%	73.9%	72.0%	61.8%	<0.01	71.5%	79.5%	73.8%	75.6%	63.2%	<0.01
	Hispanic/Latino	13.0%	9.7%	11.0%	10.4%	12.2%	19.4%		12.8%	7.5%	10.9%	10.7%	19.2%	
	Black/African American	10.9%	9.1%	8.3%	9.8%	10.8%	14.7%		10.5%	9.6%	10.0%	9.4%	13.3%	
	Asian/Other	4.5%	4.6%	2.6%	5.9%	5.0%	4.0%		5.2%	3.4%	5.4%	4.3%	4.3%	
Education	Less Than High School	25.5%	16.5%	24.4%	28.6%	29.5%	24.1%	<0.01	14.0%	18.0%	28.0%	32.6%	23.5%	<0.01
	High School Graduate	19.0%	21.8%	13.4%	17.5%	14.1%	26.7%		25.8%	17.7%	17.4%	12.8%	24.3%	
	Some College	25.4%	29.3%	24.2%	24.0%	26.2%	25.7%		26.4%	27.5%	23.6%	25.3%	26.1%	
	College Graduate	30.1%	32.4%	38.1%	30.0%	30.2%	23.4%		33.9%	36.9%	30.9%	29.3%	26.1%	
Income	<20k	33.0%	23.5%	35.6%	37.4%	38.2%	27.0%	<0.01	21.0%	30.3%	37.3%	38.2%	28.8%	<0.01
	20–25k	16.1%	24.4%	15.2%	14.4%	9.8%	19.0%		30.5%	16.6%	14.5%	12.0%	17.5%	
	25–35k	7.2%	7.2%	7.4%	6.1%	5.9%	9.1%		8.4%	6.7%	7.3%	4.5%	9.0%	
	35–45k	11.9%	13.8%	10.5%	12.3%	10.1%	12.7%		10.6%	15.3%	10.5%	10.9%	12.6%	
	45–55k	8.9%	7.4%	7.5%	7.6%	11.7%	10.2%		6.9%	6.5%	8.4%	10.3%	9.8%	
	55–65k	8.3%	7.8%	9.2%	8.2%	8.6%	8.0%		9.3%	8.0%	7.7%	8.7%	8.6%	
	65–75k	7.1%	8.2%	7.8%	5.3%	6.9%	8.2%		5.1%	9.2%	6.6%	6.4%	7.3%	
	>75k	7.6%	7.8%	6.8%	8.8%	8.9%	5.9%		8.2%	7.5%	7.7%	9.0%	6.4%	

Variable	Category	Total Sample	Difficulty Falling Asleep						Difficulty Maintaining Sleep					
			Almost Always	Often	Sometimes	Rarely	Never	P	Almost Always	Often	Sometimes	Rarely	Never	P
N (%)		**4548**	**363 (8%)**	**463 (10%)**	**966 (21%)**	**888 (20%)**	**1,868 (41%)**		**362 (8%)**	**565 (12%)**	**1,095 (24%)**	**848 (19%)**	**1,678 (37%)**	
Minutes of Exercise	Mean (SD)	166 (223)	150 (198)	173 (216)	172 (216)	183 (223)	152 (239)	0.13	175 (227)	157 (192)	167 (215)	179 (210)	159 (252)	0.55
Body Mass Index	Mean (SD)	28.7 (6.8)	29.2 (7.0)	28.8 (6.3)	28.9 (6.6)	28.4 (6.4)	28.5 (7.5)	0.55	30.2 (8.0)	29.2 (7.7)	28.8 (6.6)	28.2 (5.5)	28.5 (7.0)	0.03
Depression	Not at All	75.9%	48.6%	59.3%	72.4%	81.7%	86.2%	<0.01	52.6%	63.5%	72.0%	84.1%	84.5%	<0.01
	Several Days	17.5%	32.8%	30.1%	20.8%	13.9%	10.2%		30.5%	26.5%	20.9%	12.7%	11.3%	
	Nearly Half the Days	3.5%	6.6%	4.8%	4.6%	3.3%	1.9%		6.4%	4.9%	4.1%	2.4%	2.6%	
	All the Time	3.0%	12.0%	5.8%	2.2%	1.1%	1.7%		10.5%	5.1%	3.0%	0.9%	1.7%	

Table 2

Stepwise Ordinal Logistic Regression Model Reflecting Odds Ratios (OR) and 95% Confidence Intervals (95% CI) of Associations between 100% Increase in Dietary Variables and Difficulty Falling Asleep

Variable	Category	OR (95% CI)	P
COVARIATES FORCED INTO THE MODEL			
Number of Foods		1.01 (1.00, 1.03)	0.18
Energy (kcal) per 100		1.02 (1.01, 1.03)	0.003
Income	< $20,000	1.45 (1.14, 1.85)	0.002
	$20-$25,000	1.09 (0.81, 1.45)	0.57
	$25-$35,000	1.05 (0.81, 1.37)	0.69
	$35-$45,000	1.03 (0.78, 1.35)	0.84
	$45-$55,000	1.32 (0.99, 1.76)	0.06
	$55-$65,000	0.90 (0.63, 1.29)	0.57
	$65-$75,000	1.12 (0.80, 1.57)	0.50
	>$75,000	Reference	
Education	Less Than High School	0.76 (0.60, 0.97)	0.03
	High School	0.90 (0.72, 1.13)	0.38
	Some College	1.13 (0.91, 1.39)	0.27
	College Graduate	Reference	
Diet versus Usual	More	1.31 (0.96, 1.81)	0.09
	Less	0.92 (0.74, 1.15)	0.47
Race/Ethnicity	White	Reference	
	Hispanic	0.60 (0.50, 0.73)	<.001
	Black	0.59 (0.48, 0.72)	<.001
	Other	0.96 (0.68, 1.37)	0.84
Male Gender		0.64 (0.54, 0.76)	<.001
BMI		1.00 (0.99, 1.01)	0.96
Exercise		1.00 (1.00, 1.00)	0.25
Age		1.00 (1.00, 1.01)	0.79
Special Diet		1.22 (0.82, 1.82)	0.32
Weight loss diet		0.79 (0.49, 1.27)	0.32
Low fat/Low cholesterol diet		0.96 (0.58, 1.59)	0.87
Low salt/ sodium diet		1.40 (0.78, 2.51)	0.27
Diabetic Diet		0.67 (0.43, 1.06)	0.09
Alcohol (log)		0.99 (0.94, 1.05)	0.82
Depression	Several Days	0.18 (0.10, 0.29)	<.001
	Nearly Half the Days	0.50 (0.29, 0.84)	0.01
	All the Time	0.47 (0.27, 0.84)	0.01
	Not at All	Reference	

Variable	Category	OR (95% CI)	P
COVARIATES FORCED INTO THE MODEL			
CONTRIBUTORS OF UNIQUE VARIANCE			
Alpha-Carotene (log)		0.96 (0.93, 1.00)	0.04
Selenium (log)		0.80 (0.65, 0.99)	0.04
Dodecanoic (log ratio)		0.91 (0.84, 0.98)	0.01
Calcium (log)		0.83 (0.70, 0.98)	0.03
Hexadecanoic Acid (log ratio)		1.10 (1.02, 1.20)	0.02

Table 3

Stepwise Ordinal Logistic Regression Model Reflecting Odds Ratios (OR) and 95% Confidence Intervals (95% CI) of Associations between 100% Increase in Dietary Variables and Difficulty Maintaining Sleep

Variable	Category	OR (95% CI)	P
COVARIATES FORCED INTO THE MODEL			
Number of Foods		1.00 (0.99, 1.02)	0.77
Energy (kcal) per 100		1.02 (1.01, 1.04)	0.002
Income	< $20,000	1.22 (0.96, 1.55)	0.10
	$20-$25,000	0.90 (0.66, 1.23)	0.51
	$25-$35,000	1.06 (0.82, 1.37)	0.64
	$35-$45,000	0.95 (0.72, 1.24)	0.70
	$45-$55,000	1.09 (0.83, 1.43)	0.55
	$55-$65,000	0.85 (0.59, 1.22)	0.38
	$65-$75,000	1.03 (0.73, 1.44)	0.87
	>$75,000	Reference	
Education	Less Than High School	0.84 (0.65, 1.09)	0.19
	High School	1.03 (0.82, 1.29)	0.83
	Some College	0.98 (0.79, 1.20)	0.83
	College Graduate	Reference	
Diet versus Usual	More	1.15 (0.87, 1.52)	0.33
	Less	1.16 (0.94, 1.43)	0.17
Race/Ethnicity	White	Reference	
	Hispanic	0.69 (0.57, 0.84)	<.001
	Black	0.72 (0.59, 0.87)	0.001
	Other	0.89 (0.64, 1.25)	0.51
Male Gender		0.57 (0.48, 0.68)	<.001
BMI		1.00 (0.99, 1.01)	0.89
Exercise		1.00 (1.00, 1.00)	0.03
Age		1.01 (1.01, 1.02)	0.00
Special Diet		1.36 (0.92, 2.00)	0.13
Weight loss diet		1.02 (0.66, 1.58)	0.93
Low fat/Low cholesterol diet		0.96 (0.57, 1.62)	0.87
Low salt/ sodium diet		1.28 (0.73, 2.24)	0.39
Diabetic Diet		0.73 (0.45, 1.18)	0.19
Alcohol (log)		1.01 (0.96, 1.07)	0.73
Depression	Several Days	0.23 (0.15, 0.35)	<.001
	Nearly Half the Days	0.55 (0.36, 0.86)	0.01
	All the Time	0.50 (0.29, 0.85)	0.01
	Not at All	Reference	
CONTRIBUTORS OF UNIQUE VARIANCE			

Variable	Category	OR (95% CI)	P
COVARIATES FORCED INTO THE MODEL			
Salt Use		1.19 (1.01, 1.41)	0.04
Butanoic (log ratio)		0.81 (0.69, 0.97)	0.02
Carbohydrate (log)		0.71 (0.55, 0.92)	0.01
Dodecanoic (log ratio)		0.90 (0.84, 0.98)	0.01
Vitamin D (log)		0.84 (0.75, 0.95)	0.01
Lycopene (log)		0.98 (0.96, 1.00)	0.05
Hexanoic (log ratio)		1.25 (1.05, 1.50)	0.01
Moisture (log)		1.27 (1.05, 1.53)	0.01

Table 4

Stepwise Ordinal Logistic Regression Model Reflecting Odds Ratios (OR) and 95% Confidence Intervals (95% CI) of Associations between 100% Increase in Dietary Variables and Non-restorative Sleep

Variable	Category	OR (95% CI)	P
COVARIATES FORCED INTO THE MODEL			
Number of Foods		1.01 (1.00, 1.03)	0.12
Energy (kcal) per 100		1.00 (0.99, 1.01)	0.93
Income	< $20,000	1.01 (0.80, 1.28)	0.90
	$20-$25,000	0.92 (0.68, 1.24)	0.59
	$25-$35,000	0.96 (0.75, 1.24)	0.77
	$35-$45,000	0.84 (0.64, 1.09)	0.19
	$45-$55,000	0.98 (0.74, 1.28)	0.86
	$55-$65,000	0.87 (0.59, 1.28)	0.48
	$65-$75,000	0.96 (0.72, 1.27)	0.77
	>$75,000	Reference	
Education	Less Than High School	0.77 (0.60, 0.97)	0.03
	High School	1.02 (0.82, 1.27)	0.87
	Some College	1.23 (1.01, 1.50)	0.04
	College Graduate	Reference	
Diet versus Usual	More	1.06 (0.77, 1.47)	0.72
	Less	1.07 (0.88, 1.30)	0.52
Race/Ethnicity	White	Reference	
	Hispanic	0.51 (0.42, 0.62)	<.001
	Black	0.57 (0.47, 0.69)	<.001
	Other	0.77 (0.57, 1.04)	0.09
Male Gender		0.66 (0.56, 0.78)	<.001
BMI		1.01 (1.00, 1.02)	0.15
Exercise		1.00 (1.00, 1.00)	0.96
Age		0.98 (0.97, 0.98)	<.001
Special Diet		1.40 (0.94, 2.06)	0.09
Weight loss diet		0.73 (0.47, 1.13)	0.16
Low fat/Low cholesterol diet		0.58 (0.35, 0.95)	0.03
Low salt/ sodium diet		1.36 (0.82, 2.25)	0.23
Diabetic Diet		0.75 (0.44, 1.27)	0.29
Alcohol (log)		0.95 (0.90, 1.00)	0.06
Depression	Several Days	0.15 (0.09, 0.23)	<.001
	Nearly Half the Days	0.35 (0.22, 0.56)	<.001
	All the Time	0.44 (0.26, 0.76)	0.003
	Not at All	Reference	

Variable	Category	OR (95% CI)	P
COVARIATES FORCED INTO THE MODEL			
CONTRIBUTORS OF UNIQUE VARIANCE			
Butanoic (log ratio)		1.09 (1.00, 1.19)	0.04
Calcium (log)		0.81 (0.67, 0.98)	0.03
Vitamin C (log)		0.92 (0.86, 0.99)	0.02
Total Plain Water Drank Yesterday (log)		0.98 (0.95, 1.00)	0.09
Moisture (log)		1.41 (1.15, 1.71)	0.001
Cholesterol (log)		1.10 (1.00, 1.21)	0.05

Table 5

Stepwise Ordinal Logistic Regression Model Reflecting Odds Ratios (OR) and 95% Confidence Intervals (95% CI) of Associations between 100% Increase in Dietary Variables and Daytime Sleepiness

Variable	Category	OR (95% CI)	P
COVARIATES FORCED INTO THE MODEL			
Number of Foods		1.02 (1.01, 1.04)	0.004
Energy (kcal) per 100		1.01 (1.00, 1.02)	0.20
Income	< $20,000	1.04 (0.82, 1.33)	0.73
	$20-$25,000	0.96 (0.71, 1.29)	0.77
	$25-$35,000	0.96 (0.75, 1.24)	0.78
	$35-$45,000	0.88 (0.68, 1.14)	0.32
	$45-$55,000	0.92 (0.68, 1.24)	0.58
	$55-$65,000	0.94 (0.66, 1.33)	0.73
	$65-$75,000	1.00 (0.75, 1.33)	0.98
	>$75,000	Reference	
Education	Less Than High School	0.96 (0.76, 1.22)	0.74
	High School	1.05 (0.85, 1.30)	0.63
	Some College	1.24 (1.02, 1.51)	0.04
	College Graduate	Reference	
Diet versus Usual	More	0.86 (0.63, 1.17)	0.33
	Less	1.16 (0.95, 1.43)	0.14
Race/Ethnicity	White	Reference	
	Hispanic	0.46 (0.38, 0.56)	<.001
	Black	0.64 (0.53, 0.78)	<.001
	Other	0.89 (0.61, 1.29)	0.54
Male Gender		0.85 (0.72, 1.01)	0.07
BMI		1.02 (1.00, 1.03)	0.01
Exercise		1.00 (1.00, 1.00)	0.98
Age		0.98 (0.98, 0.99)	<.001
Special Diet		1.59 (1.03, 2.46)	0.04
Weight loss diet		0.79 (0.50, 1.24)	0.31
Low fat/Low cholesterol diet		0.56 (0.35, 0.91)	0.02
Low salt/ sodium diet		0.94 (0.51, 1.75)	0.86
Diabetic Diet		0.75 (0.40, 1.42)	0.38
Alcohol (log)		0.95 (0.90, 1.00)	0.06
Depression	Several Days	0.17 (0.11, 0.27)	<.001
	Nearly Half the Days	0.38 (0.24, 0.61)	<.001
	All the Time	0.43 (0.24, 0.77)	0.004
	Not at All	Reference	

Variable	Category	OR (95% CI)	P
COVARIATES FORCED INTO THE MODEL			
CONTRIBUTORS OF UNIQUE VARIANCE			
Moisture (log)		1.20 (0.97, 1.48)	0.09
Theobromine (log)		1.04 (1.00, 1.08)	0.08
Potassium (log)		0.70 (0.55, 0.89)	0.004
Total Plain Water Drank Yesterday (log)		0.97 (0.94, 1.00)	0.07