

Measures of Poor Sleep Quality Are Associated With Higher Energy Intake and Poor Diet Quality in a Diverse Sample of Women From the Go Red for Women Strategically Focused Research Network

Faris M. Zuraikat, PhD; Nour Makarem, PhD; Ming Liao, MS; Marie-Pierre St-Onge, PhD, FAHA; Brooke Aggarwal, EdD, MS, FAHA

Background—Poor sleep increases cardiovascular disease risk, and diet likely contributes to this relationship. However, there are limited epidemiological data on the relationship between measures of sleep quality and habitual dietary patterns. This study examined these associations in a diverse sample of women.

Methods and Results—Baseline data from 495 participants in the AHA Go Red for Women prospective cohort study (age: 20–76 years; 61% racial/ethnic minority) were examined. Sleep quality and sleep-onset latency were measured using the Pittsburgh Sleep Quality Index (PSQI) and insomnia using the Insomnia Severity Index. The validated Block Brief Food Frequency Questionnaire was used to assess diet quantity and quality. Linear regression models adjusted for confounding variables tested relationships between sleep and diet variables. Results showed that higher PSQI scores, indicative of poorer sleep quality, were associated with lower unsaturated fat intake ($\beta=-0.14$, $P<0.05$) and higher food weight ($\beta=14.9$, $P=0.02$) and added sugars consumed ($\beta=0.44$, $P=0.04$). Women with sleep-onset latency >60 minutes had higher intakes of food by weight ($\beta=235.2$, $P<0.01$) and energy ($\beta=426$, $P<0.01$), and lower intakes of whole grains ($\beta=-0.37$, $P=0.01$) than women with sleep-onset latency ≤ 15 minutes. Greater insomnia severity was associated with higher food weight ($\beta=9.4$, $P=0.02$) and energy ($\beta=17$, $P=0.01$) consumed and lower total ($\beta=-0.15$, $P=0.01$) and unsaturated fat intakes ($\beta=-0.11$, $P<0.01$).

Conclusions—Poor sleep quality was associated with greater food intake and lower-quality diet, which can increase cardiovascular disease risk. Future studies should test whether promoting sleep quality could augment efforts to improve cardiometabolic health in women. (*J Am Heart Assoc.* 2020;9:e014587. DOI: 10.1161/JAHA.119.014587.)

Key Words: diet quality • energy intake • insomnia • sleep-onset latency • sleep quality • women

Sleep is recognized as playing an essential role in cardiometabolic health,¹ but underlying mechanisms warrant further investigation. Both short sleep duration and poor sleep quality are associated with the development of obesity,^{1,2} type 2 diabetes mellitus,³ and cardiovascular disease (CVD),⁴ and it is likely that the relationship between sleep and cardiometabolic disease risk is partially mediated by diet.⁵ Indeed, experimental studies demonstrate that

restricting sleep duration leads to increases in energy intake,^{5–8} confirming associations of short sleep with higher energy intakes in observational population-based studies.^{9,10} Epidemiological data on the relation between quality of sleep and habitual dietary patterns, however, are limited. This is especially true in women, who are at increased risk for obesity¹¹ and particularly prone to poor sleep quality and sleep disturbances.¹² Thus, the purpose of the current study was to investigate the associations of overall sleep quality, sleep-onset latency, and insomnia presence and severity with diet quality in a diverse sample of women.

Sleep quality encompasses a number of factors related to the ability to fall asleep and stay asleep¹³ and extends to disordered patterns of sleep, such as insomnia.¹⁴ Few studies have examined general sleep quality and the presence of insomnia in relation to intake of foods and food groups linked to CVD risk. Poor sleep quality has been found to relate to higher intakes of confectionary¹⁵ and lower intakes of fish^{15,16} and low energy-density fruits¹⁷ and vegetables.^{15,18} Similarly, insomnia symptoms have been associated with

From the Departments of Medicine (F.M.Z., N.M., M.-P.S.-O., B.A.), and Surgery (M.L.), Sleep Center of Excellence (F.M.Z., N.M., M.-P.S.-O., B.A.), Columbia University Irving Medical Center, New York, NY.

Correspondence to: Brooke Aggarwal, EdD, MS, FAHA, Department of Medicine, Columbia University Irving Medical Center, 51 Audubon Ave, Suite 505, New York, NY 10032. E-mail: baf2108@cumc.columbia.edu

Received September 11, 2019; accepted December 18, 2019.

© 2020 The Authors. Published on behalf of the American Heart Association, Inc., by Wiley. This is an open access article under the terms of the Creative Commons Attribution-NonCommercial-NoDerivs License, which permits use and distribution in any medium, provided the original work is properly cited, the use is non-commercial and no modifications or adaptations are made.

Clinical Perspective

What Is New?

- Disturbed sleep is highly prevalent among women, and data from this study show that different measures of poor sleep quality, including greater insomnia severity, longer sleep-onset latency, and poorer overall sleep quality, are associated with higher food and energy intakes as well as poorer overall diet quality in a diverse sample of women.

What Are the Clinical Implications?

- These data indicate that unhealthy dietary patterns likely contribute to the relationship between poor sleep quality and increased risk for cardiovascular disease.
- Findings from this study suggest that incorporating strategies to enhance sleep quality into behavioral interventions may augment efforts to improve cardiovascular health among women.

increased consumption of energy,^{19,20} fat,^{19,21} and saturated fat²¹ in addition to lower intakes of protein,²² fiber,²¹ and vegetables.²⁰ Although findings are generally indicative of detrimental associations between poor sleep quality and insomnia in relation to diet quality,^{20,23} results have been inconsistent and are often narrowly focused on specific foods or nutrients. It is also difficult to determine whether observed associations will extend to different populations, particularly women varying in age, race, and ethnicity, since previous samples were typically limited to men or middle-aged and elderly women. Moreover, no study has assessed aspects of both general sleep quality and insomnia together (as opposed to one or the other) in relation to the diet in the same population. These limitations, along with the heterogeneity in sleep quality and insomnia measures, many of which have not been validated, demonstrate the need for further investigation into the extent to which quality of sleep relates to the overall diet.

The current study aims to examine the associations of both subclinical and clinical measures of sleep quality (including overall sleep quality, sleep-onset latency, and insomnia) with energy and macronutrient intakes as well as with intake of specific foods associated with disease risk. To our knowledge, this study also represents one of the earliest investigations of these relationships in a diverse cohort of women representing a broad range of life stages. We hypothesized that poor sleep quality, longer sleep-onset latency, and more severe insomnia would be associated with poorer diet quality, characterized by higher intakes of energy, total fat, saturated fat, added sugars, caffeine, and food by weight as well as lower intakes of protein, unsaturated fat, fiber, fruits and vegetables (FV), dairy, whole grains, and fish. Results of this study will

contribute to a more comprehensive understanding of the relationship between habitual patterns of sleep and diet in a population at increased risk for poor sleep and CVD,²⁴ and this could aid in the development of interventions to reduce obesity risk.

Subjects and Methods

Design

This study assessed the relation between parameters of sleep quality and dietary intakes using a cross-sectional design. Baseline data were analyzed from a diverse sample of women who encompassed different stages of adulthood and who were enrolled in a 1-year prospective cohort study of sleep and cardiovascular risk as part of the American Heart Association Go Red for Women Strategically Focused Research Network at Columbia University Irving Medical Center (CUIMC).

Participants and Procedures

English- and Spanish-speaking nonpregnant women between the ages of 20 and 79 years were eligible to participate in this population-based study. Women were recruited from New York-Presbyterian Hospital/CUIMC and neighboring communities by bilingual study staff and physicians. Eligible women (n=506) completed a baseline visit at CUIMC, during which demographic and medical history information were collected and height and weight were measured by trained study staff. In addition, participants were asked to complete self-report measures of habitual sleep and diet using validated questionnaires. Complete sleep and diet data were available for 495 women. All procedures were approved by the CUIMC Institutional Review Board. Women provided written informed consent and received financial compensation for their participation upon study completion.

Measures

Sleep assessments

Measures of habitual sleep quality were assessed at baseline using 2 validated, self-report tools: the Pittsburgh Sleep Quality Index (PSQI)²⁵ and the Insomnia Severity Index (ISI).²⁶ The PSQI is used to assess sleep patterns over the past month and can be completed by the rater alone or with a sleeping partner. This questionnaire provides both a composite score (0–21), indicative of overall sleep quality, as well as subscale values, including subjective sleep quality, sleep-onset latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime

dysfunction. Notably, higher composite PSQI scores indicate poorer sleep quality.²⁵ Total PSQI scores are also used to group individuals into dichotomous categories of overall sleep quality: poor (global sum >5) and good (global sum ≤5).^{27–29} The second exposure of interest for this analysis was sleep-onset latency, defined as the length of time between going to bed and onset of sleep. This was assessed using the response to the following question on the PSQI questionnaire: “During the past month, how long (in minutes) has it usually taken you to fall asleep each night?” Participants responded by indicating a duration in minutes, and this value was also scored 0 (≤15 minutes), 1 (16–30 minutes), 2 (31–60 minutes), or 3 (>60 minutes).²⁵

The presence of insomnia as well as insomnia severity were measured using the ISI.²⁶ The ISI comprises 7 items measuring 5 different components of insomnia: severity of insomnia symptoms, satisfaction with current sleep, extent to which current sleep interferes with daily function, perception of sleep problems, and the extent to which sleep problems are worrisome. Participants rate these items using a 4-point Likert scale ranging from “Not at all” to “Very much.” The global sum of scores for the 5 items is used to determine the level of insomnia severity, ranging from no clinically significant insomnia (scores <8) to subthreshold (moderate) insomnia (scores of 8–14), and severe clinical insomnia (scores >21). Thus, insomnia can be assessed along a continuum or can be dichotomized into (1) some, moderate, or severe insomnia (scores ≥8), or (2) no insomnia (scores <8).³⁰

Diet assessments

The Block Brief Food Frequency Questionnaire (FFQ) was used to assess habitual dietary intake over the past year. Paper versions of the questionnaire, available in both English and Spanish, were administered by trained staff. This FFQ comprises a list of ≈70 food items that are commonly consumed by multiple racial and ethnic groups.^{31,32} Participants were asked to indicate how frequently each item was consumed over the past year in addition to the amount typically eaten; visual aids were used to increase the accuracy of portion size estimation. Notably, this FFQ has been validated against more stringent diet measures.³¹ Although estimates of energy and macronutrient intakes were found to be slightly lower in the FFQ compared with 7-day food records, correlations between the 2 measures were moderate for each diet variable assessed, including fat (eg, $r=0.63$) and energy (eg, $r=0.51$),³¹ indicating reliability of the measure.

Diet variables of interest were selected based on previous experimental and epidemiological evidence of their relationships with obesity and CVD risk³³ as well as with sleep.^{9,15,16,21} Raw FFQ data were sent to NutritionQuest (Berkeley, CA) for nutrient analysis using their database. Diet

variables extracted directly from the FFQ output were total energy intake, macronutrient intakes (total fat, saturated fat, unsaturated fat, protein, carbohydrate), and fiber intake, as well as food/beverage-specific variables including intakes of fish, dairy, whole grains, added sugars, and caffeine. Two other outcome variables were created using the available data: total weight of food consumed and total FV intake. Total weight of food consumed was calculated by removing all beverages from the food item list and summing the remaining items for each participant. Total FV intake was estimated as the sum of each participant's fruit intake and vegetable intake. All diet variables were energy-adjusted as follows: (1) macronutrient intakes were calculated as a percent of total energy intake, and (2) fiber, FV, fish, dairy, whole grain, and added sugar intakes were calculated as an amount (either weight or servings) per 1000 kcal consumed.

Statistical Analysis

Descriptive statistics for sociodemographic, sleep, and medical characteristics were presented as mean±SD or as a proportion of the total sample size. The mean intakes of nutrients and foods and food groups of interest were also generated. Multivariable-adjusted linear regression models were used to assess associations between sleep and diet variables. Overall sleep quality, sleep-onset latency, and insomnia severity were analyzed as continuous variables (PSQI scores, time to fall asleep in minutes, and ISI scores, respectively). Sleep quality and insomnia were also analyzed as dichotomous variables (good sleep [PSQI scores ≤5] versus poor sleep [PSQI scores >5] and no insomnia [ISI scores <8] versus some, moderate, or severe insomnia [ISI scores ≥8]). In addition, sleep-onset latency was assessed as a categorical variable with 4 levels (0: ≤15 minutes, 1: 16–30 minutes, 2: 31–60 minutes, or 3: >60 minutes); results are presented as the comparison of the outcome between the lowest and highest scores of sleep-onset latency (0 versus 3). Outcome variables included total food weight consumed (g/d) as well as consumption of specific foods/beverages [g/1000 kcal/d [fish, added sugars], servings/1000 kcal/d [FV, dairy, whole grains], mg/day [caffeine], total energy [kcal/d], macronutrients [total fat, saturated fat, unsaturated fat, carbohydrate, and protein] [% kcal], and fiber [g/1000 kcal per day]]. All outcomes were analyzed on the continuous scale. Regression models were adjusted for confounding variables including age (y), race/ethnicity (non-Hispanic white versus racial/ethnic minority), and body mass index (kg/m²) as well as education (≥college versus <college) and health insurance status (Yes versus No), which served as a proxy for socioeconomic status. Interactions of sleep quality parameters (continuous scale) with age (20–44 versus ≥45 years, categories that have been used previously in cohort studies such as the Hispanic Community Health Study/Study of

Latinos³⁴) and race/ethnicity (White/Non-Hispanic versus Racial minority/Hispanic) were also explored. Where interactions were significant, results were stratified by group. For all analyses, the directions and magnitudes of results of regression models are provided as β -coefficient \pm SEM. All data were analyzed using SAS version 9.4 (SAS Institute, Cary, NC). Because the sleep quality–diet relationships assessed were based on a priori hypotheses, results were considered statistically significant at $P<0.05$.

Results

Subject characteristics and sleep metrics for the 495 women included in analyses (baseline sleep and diet data available) are presented in Table 1. The mean age was 37 ± 16 years, and over half of the sample (61%) was a racial or ethnic minority. The mean body mass index was 25.9 ± 5.7 kg/m² with a balanced proportion of women with overweight/obesity compared with normal weight (51% versus 49%, $P=0.93$). Average total sleep time was 6.76 ± 1.24 hours. Over one third of the sample ($\geq 38\%$) had poor sleep quality or some insomnia. In addition, 27.5% of the sample had short-sleep duration (<7 h/night) with poor sleep quality, and 24.6% had short sleep duration with insomnia. Average intakes for nutrients of interest for the 495 women who completed the FFQ are presented in Table 2. Women reported consuming 1433 ± 862 kcal/d and, on average, exceeded recommendations for total and saturated fat intakes as well as added sugars, but failed to meet recommendations for whole grains, fiber, and dairy intakes.

Associations of Overall Sleep Quality, Sleep-Onset Latency, and Insomnia With Food Intakes

Assessment of the associations of sleep-quality metrics with total and specific food intakes showed that higher PSQI scores, indicative of poorer sleep quality, were associated with a greater total weight of food consumed ($\beta=14.9\pm 6.6$ g, $P=0.02$) as well as higher intakes of added sugars ($\beta=0.44\pm 0.21$ g/1000 kcal, $P=0.04$) and caffeine ($\beta=0.84\pm 0.27$ mg, $P<0.01$) (Table 3). In contrast, PSQI scores were inversely related to dairy intake ($\beta=-0.01\pm 0.01$ servings/1000 kcal, $P=0.03$), meaning poorer sleep quality was associated with lower dairy consumption. There was a significant interaction between PSQI scores and age on whole grain intake ($P=0.04$); in younger women, higher PSQI scores were associated with lower grain intake ($\beta=-0.04\pm 0.02$ servings/1000 kcal, $P=0.02$), while this relation was not significant in older women ($\beta=-0.02\pm 0.02$, $P=0.36$). When analyzing sleep quality as a categorical variable, across all women, poor sleep quality was related to greater consumption of added sugars

Table 1. Demographic, Clinical, and Sleep Characteristics of 495 Women

Characteristic	Mean \pm SD/n (%)
Demographic	
Age, y	37 \pm 16
20–44 y	348 (70%)
≥ 45 y	147 (30%)
Race	
White	282 (57%)
Black/African-American	99 (20%)
Asian	93 (19%)
Other	21 (4%)
Ethnicity	
Non-Hispanic	357 (72%)
Hispanic	138 (28%)
Race/Ethnicity	
White/Non-Hispanic	193 (39%)
Minority/Hispanic	302 (61%)
Health insurance	
Have	375 (76%)
Do not have/Unsure/Do not know/N.A.	120 (24%)
Employment status	
Employed/students	428 (87%)
Not employed	65 (13%)
Education	
\geq College (Bachelor's degree/Postgraduate professional degree)	333 (67%)
<College	162 (33%)
Clinical/medical	
BMI (kg/m ²)	25.9 \pm 5.7
BMI class	
Normal weight	250 (51%)
Overweight/obesity	245 (49%)
Habitual sleep	
Pittsburgh Sleep Quality Index (PSQI) score*	5.6 \pm 3.8
Sleep quality[†]	
Poor (PSQI >5)	193 (39%)
Good (PSQI ≤ 5)	302 (61%)
Sleep-onset latency (m) [‡]	24.9 \pm 30.5
Insomnia Severity Index (ISI) Score [§]	7.0 \pm 6.0
Insomnia	
Somewhat, moderate, or severe (ISI ≥ 8)	188 (38%)
None (ISI <8)	306 (62%)

BMI indicates body mass index; ISI, Insomnia Severity Index; N.A., Not applicable; PSQI, Pittsburgh Sleep Quality Index.

*Global sum of PSQI scores; possible range is 0–21 with higher scores indicating poorer quality.²⁷

[†]Dichotomous categories determined from PSQI total scores.

[‡]A subscale of the PSQI.²⁷

[§]Global sum of ISI scores; possible range is 0–28 with higher scores indicating more severe insomnia.²⁹

^{||}Dichotomous categories determined from ISI total scores.

($\beta=3.41\pm 1.57$ g/1000 kcal, $P=0.03$) and caffeine ($\beta=4.57\pm 2.04$ mg, $P=0.03$) when compared with good sleep quality.

Longer sleep-onset latency in minutes was associated with higher caffeine intake ($\beta=0.09\pm 0.03$ mg, $P<0.01$). A sleep-onset latency by age interaction was observed for dairy intake ($P=0.02$). When stratified by age group, there was a significant association of sleep-onset latency with dairy intake in younger women ($\beta=-0.004\pm 0.001$ servings/1000 kcal, $P<0.01$) but not in older women ($\beta=0.0004\pm 0.001$, $P=0.73$). When analyzed as a categorical variable, across all women, the greatest level of sleep-onset latency (>60 minutes) was associated with significantly higher intakes of food by weight ($\beta=235.2\pm 79.6$ g, $P<0.01$), fish ($\beta=5.56\pm 2.22$ g/1000 kcal, $P=0.01$), and caffeine ($\beta=12.05\pm 3.32$ mg, $P<0.01$) compared with the lowest level (≤ 15 minutes). Conversely, when compared with sleep-onset latency ≤ 15 minutes, taking >60 minutes to fall asleep was associated with lower intakes of dairy ($\beta=-0.21\pm 0.08$ servings/1000 kcal, $P=0.01$) and whole grains ($\beta=-0.37\pm 0.15$ servings/1000 kcal, $P=0.01$).

Insomnia severity, assessed both as a continuous and categorical variable, was associated with the total weight of food consumed and caffeine intake. Higher total scores on the ISI were related to higher intakes of food by weight ($\beta=9.4\pm 4.0$ g, $P=0.02$) and caffeine consumption ($\beta=0.63\pm 0.16$ mg, $P<0.001$). Furthermore, in comparison to women with no insomnia, those with some, moderate, or severe insomnia had 116 ± 48.8 g higher total weight of food consumed ($P=0.02$) and a 6.1 ± 2.0 mg higher caffeine intake ($P<0.01$).

Associations of Overall Sleep Quality, Sleep-Onset Latency, and Insomnia With Energy and Nutrient Intakes

Higher PSQI scores (poorer sleep quality) were associated with lower intakes of unsaturated fat ($\beta=-0.14\pm 0.07\%$ kcal, $P<0.05$) (Table 4). Assessment of overall sleep quality as a categorical variable also showed that poor sleep quality related to lower unsaturated fat intake ($\beta=-1.41\pm 0.50\%$ kcal, $P<0.01$) in addition to lower consumption of total fat ($\beta=-2.14\pm 0.71\%$ kcal, $P<0.01$) and saturated fat ($\beta=-0.64\pm 0.30\%$ kcal, $P=0.03$).

Longer sleep-onset latency was related to higher total energy intake when analyzed as a continuous variable (time in minutes) ($\beta=3\pm 1$ kcal, $P=0.04$). This relationship was also observed when sleep-onset latency was analyzed as a categorical variable, such that taking >60 minutes to fall asleep (score of 3) was associated with a 426 ± 132 kcal greater energy intake than taking ≤ 15 minutes to fall asleep (score of 0). Analyses of interactions of sleep-onset latency (continuous variable) with race/ethnicity were significant for saturated fat ($P<0.01$) and fiber intakes ($P=0.02$). Stratified analysis showed that in White/Non-Hispanic women, longer sleep-onset latency

was associated with higher saturated fat intake ($\beta=0.2\pm 0.01\%$ kcal, $P<0.05$). Sleep-onset latency was not associated with saturated fat intake in Minority/Non-Hispanic women ($\beta=-0.006\pm 0.006\%$ kcal, $P=0.24$). Similarly, in White/Non-Hispanic women only, longer sleep-onset latency was associated with lower fiber intake ($\beta=-0.02\pm 0.01$ g/1000 kcal, $P=0.05$).

Total ISI scores, indicative of greater insomnia severity, were positively associated with total energy intake ($\beta=17\pm 7$ kcal, $P=0.01$) and inversely related to total fat ($\beta=-0.15\pm 0.06\%$ kcal, $P=0.01$) and unsaturated fat intakes ($\beta=-0.11\pm 0.04\%$ kcal, $P<0.01$). These relations persisted in models where insomnia was evaluated as a categorical variable. Compared with no insomnia, having some, moderate, or severe insomnia was associated with 205 ± 81 kcal higher energy intakes ($P=0.01$), $1.8\pm 0.7\%$ lower energy consumed from fat ($P=0.01$), and $1.3\pm 0.5\%$ lower energy consumed from unsaturated fat ($P=0.01$). Notably, none of the sleep metrics were related to protein or carbohydrate intakes (all $P>0.08$).

Discussion

Assessment of habitual patterns of sleep and diet in a diverse sample of women demonstrated that aspects of poor sleep quality, including longer sleep-onset latency and greater insomnia severity, as well as poorer overall sleep quality are associated with greater energy intake and lower-quality diets. These findings build upon the well-established link between sleep duration and diet^{1,5} by demonstrating that quality of sleep is also related to overall caloric intake and the amount and types of food consumed. Importantly, this is one of the earliest observations of associations of overall sleep quality, sleep-onset latency, and insomnia with diet quality in women across a broad range of ages and race/ethnicities, thereby extending findings of a sleep-diet relation previously demonstrated in populations differing in characteristics such as age^{18,33,35} and sex.^{20,21} By showing that poor sleep quality can be linked to overeating and poor diet quality in women, this study provides insight into a potential mechanism underlying the relationship between sleep quality and cardiometabolic health in a population at increased risk for sleep disturbances and prone to CVD.²⁴

Our study, similar to previous studies of sleep and diet,^{15,17,18} found that overall sleep quality was associated with consumption of certain nutrients and foods associated with disease risk. The association between poor overall sleep quality and greater consumption of added sugars observed in the current study aligns with previous findings that intakes of confectionary and sugar-sweetened beverages were higher in middle-aged Japanese women reporting poor, compared with good, sleep quality.¹⁵ Given that high intake of added sugars

Table 2. Energy, Nutrient, and Food Intakes of 495 Women*

Diet Variable	Full Sample (n=495)	Sleep Quality		P Value of Mean Difference [†]	Effect Size [‡]	Presence of Insomnia		P Value of Mean Difference [†]	Effect Size [‡]
		Good (n=308)	Poor (n=191)			None (n=308)	Some/Moderate/Severe (n=188)		
Energy and nutrients									
Total energy intake (kcal)	1433±862	1375±644	1518±1120	0.110	0.17	1349±601	1565±1158	0.018 [§]	0.25
Total fat intake (% total kcal)	39.2±7.5	40.0±7.6	37.9±7.0	0.002 [§]	0.29	39.9±7.6	38.0±7.1	0.007 [§]	0.25
Saturated fat intake (% total kcal)	12.7±3.1	12.9±3.2	12.2±2.9	0.019 [§]	0.23	12.9±3.2	12.3±3.1	0.035 [§]	0.20
Unsaturated fat intake (% total kcal)	23.4±5.3	23.9±5.4	22.5±4.9	0.004 [§]	0.26	23.8±5.5	22.6±4.9	0.014 [§]	0.23
Protein intake (% total kcal)	15.9±3.4	15.9±3.5	15.8±3.2	0.942	0.07	15.8±3.5	16.0±3.2	0.467	0.07
Carbohydrate intake (% total kcal)	44.0±9.0	43.2±8.8	45.5±9.1	0.017 [§]	0.22	43.4±8.8	45.0±9.2	0.044 [§]	0.19
Fiber intake (g/1000 kcal)	11.6±4.7	11.4±4.4	11.8±5.2	0.485	0.08	11.5±4.3	11.7±5.3	0.682	0.04
Foods and food groups									
Total weight of food consumed, g	918.2±514.5	882.7±402.3	975.7±654.0	0.079	0.18	871.8±392.4	995.5±663.2	0.021 [§]	0.24
Fruit and vegetable intake (servings/1000 kcal)	3.8±2.4	3.8±2.2	3.9±2.7	0.770	0.03	3.8±2.3	3.8±2.5	0.888	0.01
Fish intake (g/1000 kcal)	12.3±14.8	12.1±14.8	12.7±14.8	0.658	0.11	11.7±14.4	13.4±15.5	0.222	0.10
Dairy intake (servings/1000 kcal)	0.8±0.5	0.8±0.5	0.8±0.5	0.309	0.07	0.8±0.5	0.8±0.5	0.300	0.03
Whole grain intakes (servings/1000 kcal)	2.3±0.5	2.3±1.0	2.2±1.0	0.418	0.26	2.3±1.0	2.3±1.0	0.744	0.18
Added sugars intake (g/1000 kcal)	47.4±16.7	46.6±15.7	50.2±17.8	0.003 [§]	0.24	46.2±16.3	49.3±17.2	0.050 [§]	0.29
Caffeine intake, mg	7.0±21.8	4.9±12.6	10.2±31.1	0.026 [§]	0.24	4.6±12.1	10.8±31.6	0.010 [§]	0.29

*Values presented as mean±SD unless indicated otherwise.
[†]Analyzed using independent-samples t tests.
[‡]Cohen's D value.
[§]Statistical significance at P<0.05.

Table 3. Multivariable-Adjusted Associations of Sleep With Food and Food Group Intakes

Predictor	Outcome	$\beta \pm SE$	P Value
PSQI score*	Food weight consumed	14.9 \pm 6.6	0.024 [†]
	Fruit vegetable intake	0.02 \pm 0.03	0.588
	Fish intake	0.07 \pm 0.18	0.714
	Dairy intake	-0.01 \pm 0.01	0.030 [†]
	Whole grain intake	-0.02 \pm 0.01	0.072
	Added sugars intake	0.44 \pm 0.21	0.036 [†]
	Caffeine	0.84 \pm 0.27	0.002 [†]
Sleep quality [‡]	Food weight consumed	79.6 \pm 49.1	0.106
	Fruit vegetable intake	0.10 \pm 0.23	0.676
	Fish intake	0.06 \pm 1.4	0.964
	Dairy intake	-0.07 \pm 0.05	0.151
	Whole grain intake	-0.07 \pm 0.09	0.470
	Added sugars intake	3.41 \pm 1.57	0.031 [†]
	Caffeine	4.57 \pm 2.04	0.026 [†]
Sleep-onset latency [§]	Food weight consumed	1.1 \pm 0.8	0.155
	Fruit vegetable intake	-0.003 \pm 0.004	0.387
	Fish intake	0.03 \pm 0.02	0.232
	Dairy intake	-0.001 \pm 0.001	0.227
	Whole grain intake	-0.001 \pm 0.001	0.408
	Added sugars intake	0.02 \pm 0.02	0.465
	Caffeine	0.09 \pm 0.03	0.004 [†]
Sleep-onset latency score	Food weight consumed	235.2 \pm 79.6	0.003 [†]
	Fruit vegetable intake	0.09 \pm 0.32	0.803
	Fish intake	5.56 \pm 2.22	0.013 [†]
	Dairy intake	-0.21 \pm 0.08	0.010 [†]
	Whole grain intake	-0.37 \pm 0.15	0.015 [†]
	Added sugars intake	2.97 \pm 2.59	0.252
	Caffeine	12.05 \pm 3.32	0.003 [†]
ISI score [¶]	Food weight consumed	9.4 \pm 4.0	0.018 [†]
	Fruit vegetable intake	-0.01 \pm 0.02	0.698
	Fish intake	0.05 \pm 0.11	0.626
	Dairy intake	-0.005 \pm 0.004	0.221
	Whole grain intake	-0.002 \pm 0.008	0.836
	Added sugars intake	0.22 \pm 0.13	0.093
	Caffeine	0.63 \pm 0.16	0.0001 [†]
Insomnia [#]	Food weight consumed	116.0 \pm 48.8	0.018 [†]
	Fruit vegetable intake	0.02 \pm 0.23	0.940
	Fish intake	0.60 \pm 1.37	0.663
	Dairy intake	-0.07 \pm 0.05	0.166
	Whole grain intake	0.06 \pm 0.09	0.539
	Added sugars intake	1.87 \pm 1.58	0.235
	Caffeine	6.07 \pm 2.03	0.003 [†]

ISI indicates Insomnia Severity Index; PSQI, Pittsburgh Sleep Quality Index. Multivariable-adjusted linear regression models adjusted for age, BMI, race/ethnicity, education and health insurance.

*Higher scores indicate poorer sleep.

[†]Statistical significance at $P < 0.05$.

[‡]Score of 1 indicates poor sleep quality; 0 indicates good sleep quality.

[§]Higher values indicate longer sleep-onset latency (ie, time to fall asleep).

^{||}Score of 3 indicates the longest category of sleep-onset latency (>60 m); score of 0 indicates the shortest category of sleep-onset latency (≤ 15 m).

[¶]Higher scores indicate more severe insomnia.

[#]Score of 1 indicates some, moderate, or severe insomnia; 0 indicates no insomnia.

increases the risk for development of obesity and type 2 diabetes mellitus,³⁶ it is possible that overconsumption of sugar-sweetened foods and beverages in response to poor sleep quality moderates the relationship between sleep and glucose dysregulation.³⁷ Experimental studies testing the effect of varying sleep quality on dietary intakes and subsequent glucose and insulin levels will be needed to confirm this speculation. Contrary to our hypothesis, sleep quality was inversely related to total fat intake and not associated with saturated fat intake. This is divergent from studies on sleep duration and architecture, which find that that shorter and lighter sleep relate to greater total fat and saturated fat intakes, respectively.^{38,39} It is notable, however, that good sleep quality in this sample was also related to higher unsaturated fat intake; consumption of polyunsaturated fatty acids, for instance, can reduce CVD risk.⁴⁰ If a large proportion of calories from fat are in the form of unsaturated fat, as is the case in this cohort (45%; data not shown), current results would support a relation between good sleep quality and a healthier dietary fatty acid profile.

Women are at heightened risk for obesity,¹¹ and the most influential factor in determining body weight is energy intake.⁴¹ Data on the association of overall sleep quality with energy intake are both limited and inconsistent.^{15,18} While we did not find overall sleep quality to be related to energy intake in this group of women, longer sleep-onset latency, a component of poor sleep quality and insomnia, was associated with higher caloric intake. Similarly, longer sleep-onset latency correlated with greater intake of food by weight. This could indicate that difficulty falling asleep promotes selection and consumption of larger food portions; portion size is known to be a primary determinant of energy intake.⁴² To our knowledge, this is the first observation of these relations in a population-based study. If we interpret the directionality as longer sleep-onset latency contributing to overeating, our findings suggest that strategies to reduce the time it takes to fall asleep, independent of overall sleep quality, could potentially mitigate obesity risk through lowering caloric intake. An alternative interpretation could be that diet quality affects the time it takes to fall asleep, which could in turn influence CVD risk via poor sleep quality. In this case, recommendations to improve dietary intakes should be tested to determine their impact on sleep and CVD risk.

This study extended beyond assessment of general sleep quality to examine the relation between insomnia and diet. Despite women being at increased risk for sleep disorders,¹² few studies have evaluated associations of these 2 aspects of sleep health with diet in women. Data from this study, comprising racially and ethnically diverse women across a broad range of ages, corroborates findings that severity of insomnia is associated with obesogenic dietary patterns in men.^{20,21} Some differences are observed,

Table 4. Multivariable-Adjusted Associations of Sleep With Energy and Nutrient Intakes

Predictor	Outcome	$\beta \pm SE$	P Value
PSQI score*	Total energy intake	19±11	0.082
	% Fat intake	-0.19±0.10	0.052
	% Saturated fat intake	-0.05±0.04	0.192
	% Unsaturated fat intake	-0.14±0.07	0.048 [†]
	% Protein intake	-0.003±0.04	0.951
	% Carbohydrate intake	0.18±0.12	0.116
	Fiber intake	0.04±0.60	0.511
Sleep quality [‡]	Total energy intake	108±82	0.184
	% Fat intake	-2.14±0.71	0.003 [†]
	% Saturated fat intake	-0.64±0.30	0.031 [†]
	% Unsaturated fat intake	-1.41±0.50	0.005 [†]
	% Protein intake	-0.09±0.32	0.776
	% Carbohydrate intake	1.47±0.85	0.085
	Fiber intake	0.32±0.45	0.475
Sleep-onset latency [§]	Total energy intake	3±1	0.038 [†]
	% Fat intake	-0.01±0.01	0.598
	% Saturated fat intake	-0.001±0.005	0.852
	% Unsaturated fat intake	-0.005±0.008	0.541
	% Protein intake	-0.004±0.005	0.433
	% Carbohydrate intake	0.01±0.01	0.432
	Fiber intake	-0.004±0.007	0.536
Sleep-onset latency score	Total energy intake	426±132	0.001 [†]
	% Fat intake	-1.31±1.17	0.266
	% Saturated fat intake	-0.38±0.49	0.429
	% Unsaturated fat intake	-0.95±0.83	0.253
	% Protein intake	0.27±0.52	0.612
	% Carbohydrate intake	0.24±1.4	0.862
	Fiber intake	0.06±0.74	0.930
Insomnia Severity Index score [¶]	Total energy intake	17±7	0.012 [†]
	% Fat intake	-0.15±0.06	0.011 [†]
	% Saturated fat intake	-0.03±0.02	0.179
	% Unsaturated fat intake	-0.11±0.04	0.007 [†]
	% Protein intake	0.00±0.03	1.000
	% Carbohydrate intake	0.11±0.07	0.120
	Fiber intake	-0.005±0.37	0.894
Insomnia [#]	Total energy intake	205±81	0.012 [†]
	% Fat intake	-1.81±0.71	0.011 [†]
	% Saturated fat intake	-0.52±0.30	0.080
	% Unsaturated fat intake	-1.25±0.50	0.013 [†]
	% Protein intake	0.17±0.32	0.591
	% Carbohydrate intake	1.34±0.85	0.118
	Fiber intake	0.20±0.45	0.663

ISI indicates Insomnia Severity Index; PSQI, Pittsburgh Sleep Quality Index.

Multivariable-adjusted linear regressions adjusted for age, body mass index, race/ethnicity, education, and health insurance status.

*Higher scores indicate poorer sleep.

[†]Statistical significance at $P < 0.05$.

[‡]Score of 1 indicates poor sleep quality; 0 indicates good sleep quality.

[§]Higher values indicate longer sleep-onset latency (ie, time to fall asleep).

^{||}Score of 3 indicates the longest category of sleep-onset latency (>60 m); score of 0 indicates the shortest category of sleep-onset latency (≤15 m).

[¶]Higher scores indicate more severe insomnia.

[#]Score of 1 indicates some, moderate, or severe insomnia; 0 indicates no insomnia.

however, between the studies conducted in different sexes. In men, insomnia symptoms have been shown to relate to the amounts of different macronutrients,^{21,22} fiber,²¹ and FV²⁰ consumed. These relationships were not observed in the current sample of women. A novel finding from this study is that presence of insomnia corresponded with substantially greater intake of food by weight. This is notable given that consumption of large food portions, particularly of energy-dense foods, has contributed to the obesity epidemic.^{42,43} Indeed, severity of insomnia was also found to be positively associated with energy intake in this sample. Given the key role of energy intake in determining weight change,⁴¹ these data suggest that overconsumption of energy may mediate a relation between insomnia and obesity in women.

It is of interest to consider possible mechanisms underlying the observed relationships between sleep quality and dietary patterns, as this could aid in the development of strategies to counter overeating in individuals with acute or chronic poor sleep. One way in which poor sleep quality may lead to excessive food and energy intake is through stimulating hunger and/or suppressing satiety signals. Insufficient sleep leads to orexigenic changes in both subjective and objective measures of hunger and fullness.^{5,44} For example, experimental fragmentation of sleep, which altered sleep quality but not duration, led to reductions in the anorexigenic hormone glucagon-like peptide-1 and corresponding ratings of postmeal fullness.⁴⁵ Similarly, insomnia can influence activity in the hippocampus, a region of the brain involved in the regulation of food intake, which could have downstream effects on eating behaviors.⁴⁶ These potential mechanisms could be used to explain relations observed in the current data set. We found that components of poor sleep quality, particularly insomnia, were associated with increased intake of food by weight and energy. Fullness is largely impacted by the weight or volume of food consumed⁴⁷; therefore, it could be the case that women with insomnia consume a greater amount of food in an effort to feel satiated. If this is achieved by consuming calorie-dense foods, such as those with added sugars, corresponding energy intakes would be higher, as the data suggest. Given that women with insomnia may be predisposed to consuming larger portions, 1 method to counter overconsumption of energy in these individuals could be to target food energy density, promoting consumption of a low energy-density diet. This would allow for intake of their typical larger food portions while maintaining a lower caloric intake and promoting satiety.^{47,48} Another potential explanation for the observed relations between sleep and food weight consumed is that intake of a greater weight of food causes gastrointestinal discomforts, making it harder to fall asleep or remain asleep.

This study provides novel contributions to the current literature on sleep and diet quality but also highlights avenues

for future research. As noted, sleep quality is less frequently studied in the context of diet than is sleep duration. By assessing various measures of sleep quality, including insomnia, the results of this study supplement current knowledge of the sleep-diet relation and may be indicative of a potential mechanism underlying the relation between sleep quality and cardiometabolic health. Moreover, use of validated measures of sleep and diet are a strength of this study, as many previous studies have relied on measures of habitual sleep quality or insomnia that were not previously validated against objective sleep measures. The FFQ is also a valid measure of dietary patterns³¹; however, it is noteworthy that this tool, like all other self-reported diet assessments, is susceptible to underreporting.⁴⁹ Given the size of the sample, objectively measured food intake or use of doubly-labeled water would not have been feasible. An additional strength of this study is the evaluation of these relationships in a diverse sample of women, which is important given that women have increased susceptibility to sleep disturbances¹² and obesity¹¹ and are thereby prone to CVD.²⁴ Future research would benefit from recruitment of an even larger sample, because characteristics such as age or race/ethnicity could modify observed relations. Results from this study suggest that this could be the case, but the study was not powered to test such interactions. A limitation of this analysis is that neither directionality, nor causality, can be determined from this cross-sectional study. There is evidence of a potential bi-directional relation between sleep quality and diet, which requires further investigation.⁵⁰ Thus, an important next step would be to assess these associations in a longitudinal or experimental design with objective measures to determine whether sleep quality leads to an obesogenic diet, whether poor diet quality contributes to poor sleep, or both.⁵¹

Using cross-sectional data from a racially/ethnically diverse sample of women from different age groups, we found that poor overall sleep quality, longer sleep-onset latency, and insomnia presence and severity were associated with poorer diet quality. Most notably, longer sleep-onset latency, a marker of poor sleep and insomnia, as well as insomnia itself, related to higher energy intakes. Given that poor diet quality and overconsumption of energy are established risk factors for the development of obesity and other cardiometabolic diseases, future studies should test whether promoting sleep quality (eg, through behavioral treatments⁵² such as cognitive behavioral therapy), can augment lifestyle interventions to treat and prevent obesity and CVD in women.

Acknowledgements

FMZ, NM, MPSO, and BA designed the research plan; FMZ and NM designed the analysis plan; ML conducted the statistical

analysis; FMZ took the lead on writing the paper; NM, MPSO, and BA contributed to the writing and provided critical review of the paper; FMZ, MPSO, and BA had responsibility for final content. BA oversaw the study and research process. All authors read and approved the final manuscript.

Sources of Funding

This study was funded by an AHA Go Red for Women Strategically Focused Research Network Award: 16SFRN27960011 (PI: BA) and 16SFRN27950012 (PI: MPSO). Dr Makarem is supported by an AHA Soter Collaborative Award: 16SFRN27880000-1 (PI: NM). Dr Zuraikat has received support from postdoctoral fellowships from AHA: 16SFRN27880000 (PI: MPSO) and NHLBI: T32HL007343-42.

Disclosures

None.

References

1. St-Onge M-P, Grandner MA, Brown D, Conroy MB, Jean-Louis G, Coons M, Bhatt DL. Sleep duration and quality: impact on lifestyle behaviors and cardiometabolic health: a scientific statement From the American Heart Association. *Circulation*. 2016;134.
2. Beccuti G, Pannain S. Sleep and obesity. *Curr Opin Clin Nutr Metab Care*. 2011;14:402–412.
3. 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.
4. Kwok CS, Kontopantelis E, Kuligowski G, Gray M, Muhyaldeen A, Gale CP, Peat GM, Cleator J, Chew-Graham C, Loke YK, Mamas MA. Self-Reported sleep duration and quality and cardiovascular disease and mortality: a dose-response meta-analysis. *J Am Heart Assoc*. 2018;7:e008552. DOI: 10.1161/JAHA.118.008552.
5. St-Onge M-P. Sleep-obesity relation: underlying mechanisms and consequences for treatment. *Obes Rev*. 2017;18:34–39.
6. Bosy-Westphal A, Hinrichs S, Jauch-Chara K, Hitzte B, Later W, Wilms B, Settler U, Peters A, Kiosz D, Müller MJ. Influence of partial sleep deprivation on energy balance and insulin sensitivity in healthy women. *Obes Facts*. 2008;1:266–273.
7. 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.
8. 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.
9. 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.
10. Dashti HS, Scheer FA, Jacques PF, Lamon-Fava S, Ordovás JM. Short sleep duration and dietary intake: epidemiologic evidence, mechanisms, and health implications. *Adv Nutr*. 2015;6:648–659.
11. Lovejoy JC, Sainsbury A. Sex differences in obesity and the regulation of energy homeostasis. *Obes Rev*. 2009;10:154–167.
12. Mallampalli MP, Carter CL. Exploring sex and gender differences in sleep health: a Society for Women's Health Research Report. *J Women's Health*. 2014;23:553–562.
13. Ohayon M, Wickwire EM, Hirshkowitz M, Albert SM, Avidan A, Daly FJ, Dauvilliers Y, Ferri R, Fung C, Gozal D, Hazen N, Krystal A, Lichstein K, Mallampalli M, Plazzi G, Rawding R, Scheer FA, Somers V, Vitiello MV. National Sleep Foundation's sleep quality recommendations: first report. *Sleep Health*. 2017;3:6–19.
14. Buysse DJ. Insomnia. *JAMA*. 2013;309:706.

15. Katagiri R, Asakura K, Kobayashi S, Suga H, Sasaki S, Sasaki S. Low intake of vegetables, high intake of confectionary, and unhealthy eating habits are associated with poor sleep quality among middle-aged female Japanese workers. *J Occup Health*. 2014;56:359–368.
16. Del Brutto OH, Mera RM, Ha J, Gillman J, Zambrano M, Castillo PR. Dietary fish intake and sleep quality: a population-based study. *Sleep Med*. 2016;17:126–128.
17. Kong F, Li H, Xu G, Ying Y, Gong Q, Zhao J, Zhang X, Zhang L, Liu S, Han L. Association of dietary behaviors and sleep quality: results from the adults chronic diseases and risk factors survey of 2015 in Ningbo, China. *Int J Environ Res Public Health*. 2018;15:1823.
18. 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.
19. Zadeh SS, Begum K. Comparison of nutrient intake by sleep status in selected adults in Mysore, India. *Nutr Res Pract*. 2011;5:230–235.
20. Cheng FW, Li Y, Winkelman JW, Hu FB, Rimm EB, Gao X. Probable insomnia is associated with future total energy intake and diet quality in men. *Am J Clin Nutr*. 2016;104:462–469.
21. Tan X, Alén M, Cheng SM, Mikkola TM, Tenhunen J, Lyytikäinen A, Wiklund P, Cong F, Saarinen A, Tarkka I, Partinen M, Cheng S. Associations of disordered sleep with body fat distribution, physical activity and diet among overweight middle-aged men. *J Sleep Res*. 2015;24:414–424.
22. Tanaka E, Yatsuya H, Uemura M, Murata C, Otsuka R, Toyoshima H, Tamakoshi K, Sasaki S, Kawaguchi L, Aoyama A. Associations of protein, fat, and carbohydrate intakes with insomnia symptoms among middle-aged Japanese workers. *J Epidemiol*. 2013;23:132–138.
23. Stefan L, Radman I, Podnar H, Vrgoč G, Štefan L, Radman I, Podnar H, Vrgoč G. Sleep duration and sleep quality associated with dietary index in free-living very old adults. *Nutrients*. 2018;10:1748.
24. Benjamin EJ, Muntner P, Alonso A, Bittencourt MS, Callaway CW, Carson AP, Chamberlain AM, Chang AR, Cheng S, Das SR, Delling FN, Djousse L, Elkind MSV, Ferguson JF, Fornage M, Jordan LC, Khan SS, Kissela BM, Knutson KL, Kwan TW, Lackland DT, Lewis TT, Lichtman JH, Longenecker CT, Loop MS, Lutsey PL, Martin SS, Matsushita K, Moran AE, Mussolino ME, O'Flaherty M, Pandey A, Perak AM, Rosamond WD, Roth GA, Sampson UKA, Satou GM, Schroeder EB, Shah SH, Spartano NL, Stokes A, Tirschwell DL, Tsao CW, Turakhia MP, VanWagner LB, Wilkins JT, Wong SS, Virani SS; Subcommittee on behalf of the AHAC on E and PSC and SS. Heart disease and stroke statistics—2019 Update: a report from the American Heart Association. *Circulation*. 2019;139:e56–e528.
25. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh sleep quality index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989;28:193–213.
26. Morin CM. Insomnia: psychological assessment and management—PsychNET. CM MORIN, ed. *Treatment Manuals for Practitioners. Insomnia: Psychological Assessment and Management*. New York, NY: Guilford Press; 1993. Available at <https://psycnet.apa.org/record/1993-98362-000>. Accessed June 10, 2019.
27. Aggarwal B, Makarem N, Shah R, Emin M, Wei Y, St-Onge M-P, Jelic S. Effects of inadequate sleep on blood pressure and endothelial inflammation in women: findings from the American Heart Association go red for women strategically focused research network. *J Am Heart Assoc*. 2018;7:e008590. DOI: 10.1161/JAHA.118.008590.
28. Bush AL, Armento MEA, Weiss BJ, Rhoades HM, Novy DM, Wilson NL, Kunik ME, Stanley MA. The Pittsburgh Sleep Quality Index in older primary care patients with generalized anxiety disorder: psychometrics and outcomes following cognitive behavioral therapy. *Psychiatry Res*. 2012;199:24–30.
29. Filiatrault M-L, Chaput J-P, Drapeau V, Tremblay A. Eating behavior traits and sleep as determinants of weight loss in overweight and obese adults. *Nutr Diabetes*. 2014;4:e140.
30. Bastien CH, Vallières A, Morin CM. Validation of the Insomnia Severity Index as an outcome measure for insomnia research. *Sleep Med*. 2001;2:297–307.
31. Block G, Hartman AM, Naughton D. A reduced dietary questionnaire: development and validation. *Epidemiology*. 1990;1:58–64.
32. NutritionQuest. No Title. Assessment and Analysis Services. Food Frequency Questionnaires for Adults: Block Questionnaire—Block Brief 2000. Available at: <https://nutritionquest.com/assessment/list-of-questionnaires-and-screens/>. Accessed October 5, 2015.
33. Anand SS, Hawkes C, de Souza RJ, Mentz A, Dehghan M, Nugent R, Zylinaik MA, Weis T, Bernstein AM, Krauss RM, Kromhout D, Jenkins DJA, Malik V, Martinez-Gonzalez MA, Mozaffarian D, Yusuf S, Willett WC, Popkin BM. Food consumption and its impact on cardiovascular disease: importance of solutions focused on the globalized food system. *J Am Coll Cardiol*. 2015;66:1590–1614.
34. Sorlie PD, Avilés-Santa LM, Wassertheil-Smoller S, Kaplan RC, Daviglius ML, Giachello AL, Schneiderman N, Raji L, Talavera G, Allison M, LaVange L, Chambless LE, Heiss G. Design and implementation of the hispanic community health study of latinos. *Ann Epidemiol*. 2010;20:629–641.
35. Min C, Kim H-J, Park I-S, Park B, Kim J-H, Sim S, Choi HG. The association between sleep duration, sleep quality, and food consumption in adolescents: a cross-sectional study using the Korea Youth Risk Behavior Web-based Survey. *BMJ Open*. 2018;8:e022848.
36. Bray GA, Popkin BM. Dietary sugar and body weight: have we reached a crisis in the epidemic of obesity and diabetes? Health be damned! Pour on the sugar. *Diabetes Care*. 2014;37:950–956.
37. Spiegel K, Tasali E, Leproul R, Van Cauter E. Effects of poor and short sleep on glucose metabolism and obesity risk. *Nat Rev Endocrinol*. 2009;5:253–261.
38. St-Onge M-P, Roberts AL, Chen J, Kelleman M, O'Keefe 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.
39. St-Onge M-P, Roberts A, Shechter A, Choudhury AR. Fiber and saturated fat are associated with sleep arousals and slow wave sleep. *J Clin Sleep Med*. 2016;12:19–24.
40. Kris-Etherton PM, Hecker KD, Binkoski AE. Polyunsaturated fatty acids and cardiovascular health. *Nutr Rev*. 2004;62:414–426.
41. Hall KD, Heymsfield SB, Kemnitz JW, Klein S, Schoeller DA, Speakman JR. Energy balance and its components: implications for body weight regulation. *Am J Clin Nutr*. 2012;95:989–994.
42. Zuraikat FM, Smethers AD, Rolls BJ. The influence of portion size on eating and drinking. In: Meiselman HL, ed. *Handbook of Eating and Drinking: Interdisciplinary Perspectives*. Cham: Springer Nature; 2019:1–36.
43. Rolls BJ. The supersizing of america: portion size and the obesity epidemic. *Nutr Today*. 2003;38:42–53.
44. Gonnissen HKJ, Adam TC, Hursel R, Rutters F, Verhoef SPM, Westerterp-Plantenga MS. Sleep duration, sleep quality and body weight: parallel developments. *Physiol Behav*. 2013;121:112–116.
45. Gonnissen HKJ, Hursel R, Rutters F, Martens EAP, 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.
46. Stevenson RJ, Francis HM. The hippocampus and the regulation of human food intake. *Psychol Bull*. 2017;143:1011–1032.
47. Rolls BJ. The relationship between dietary energy density and energy intake. *Physiol Behav*. 2009;97:609–615.
48. Smethers AD, Rolls BJ. Dietary management of obesity: cornerstones of healthy eating patterns. *Med Clin North Am*. 2018;102:107–124.
49. Schoeller DA. Limitations in the assessment of dietary energy intake by self-report. *Metabolism*. 1995;44:18–22.
50. St-Onge M-P, Zuraikat FM. Reciprocal roles of sleep and diet in cardiovascular health: a review of recent evidence and a potential mechanism. *Curr Atheroscler Rep*. 2019;21:11.
51. Castro-Diehl C, Wood AC, Redline S, Reid M, Johnson DA, Maras JE, Jacobs DR, Shea S, Crawford A, St-Onge M-P. Mediterranean diet pattern and sleep duration and insomnia symptoms in the Multi-Ethnic Study of Atherosclerosis. *Sleep*. 2018;41:zsy158.
52. Morin CM, Bootzin RR, Buysse DJ, Edinger JD, Espie CA, Lichstein KL. Psychological and behavioral treatment of insomnia: update of the recent evidence (1998–2004). *Sleep*. 2006;29:1398–1414.