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Original Article

Relationships among dietary nutrients and subjective sleep, objective sleep, and napping in women

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ABSTRACT

Objective: To describe which dietary nutrient variables are related to subjective and objective habitual sleep and subjective and objective napping.
Methods: Participants were 459 post-menopausal women enrolled in the Women's Health Initiative. Objective sleep was estimated using one week of actigraphy. Subjective sleep was prospectively estimated with a daily sleep diary. Dietary nutrients were calculated from food frequency questionnaires.
Results: The most significant correlations were with subjective napping, including (from strongest to weakest): total fat, calories, saturated fat, monounsaturated fat, trans fat, water, proline, serine, tyrosine, phenylalanine, valine, cholesterol, leucine, glutamic acid, ash, isoleucine, histidine, sodium, tryptophan, protein, threonine, cystine, methionine, phosphorous, polyunsaturated fat, animal protein, aspartic acid, arginine, lysine, alanine, caffeine, riboflavin, gamma-tocopherol, glycine, retinol, delta-tocopherol, Vitamin D, and selenium. Actigraphic nocturnal sleep duration was negatively associated with total fat, monounsaturated fat, trans fat, saturated fat, polyunsaturated fat, calories, gamma-tocopherol, cholesterol, and alpha-tocopherol-eq.
Conclusions: Actigraphic total sleep time was negatively associated with intake of fats. Subjective napping, which may be a proxy for subjective sleepiness, was significantly related to fat intake as well as intake of meat.

1. Introduction

Epidemiological and laboratory studies have indicated that self-reported short sleep duration is associated with increased risks for metabolic disruption, including impaired glucose tolerance, impaired insulin resistance, increased ghrelin, decreased leptin, and increased body mass index (BMI) [1–12]. These findings may partially explain the increased mortality associated with short sleep duration, which has been replicated by many studies [13,14]. But the role of diet in these sleep-related metabolic phenomena is currently unknown.

Although epidemiological studies have benefited from large numbers of participants, they have not measured sleep using prospective or objective methods. Thus, it is not known whether these associations are caused by sleep or by other factors. Additionally, while laboratory studies carefully measured sleep, the controlled setting of the laboratory offered little ecological validity, and the small number of participants provided limited generalizability [13]. Thus, it is unknown whether these carefully-recorded observations will translate to considerations of population health.

The present study helps to address these issues by using sleep recorded prospectively with sleep diaries and objectively using actigraphy, both well-validated estimates of habitual sleep [15–19]. Additionally, this study examined dietary variables using validated nutritional assessments [20]. Finally, by employing a large sample of women from the Women's Health Initiative [21,22], we were able to demonstrate sufficient power to detect subtle relationships, at least in this group of older women. Thus, the present study aims to describe the relationships among dietary nutrient variables and subjective and objective sleep as well as subjective and objective estimates of napping. Using this approach, we explored which dietary nutrients were associated with which sleep variables.

2. Methods

2.1. Subjects

Subjects were 423 women recruited as part of an ancillary study of the Women's Health Initiative (WHI), a large, multi-site, longitu-

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dinal study of health in post-menopausal women (a description of methods and rationale has been published previously [21,22]). All women were post-menopausal (mean age 68, SD 7.76, range 50–81). Baseline characteristics for education, income and BMI are included in Table 1.

Recruitment emphasized ethnic diversity. Clinical measurements included weight and height (to compute BMI) obtained by personnel during clinic visits [21]. Additional questionnaires measured numerous demographic variables, including age, education, income, and estimated minutes of daily moderate/strenuous physical activity (computed with questions addressing estimates of time spent doing various activities in general) [21]. Several previous reports of data from these subjects have appeared [23–30]. In addition, each participant completed a Structured Clinical Interview for the DSM-IV (SCID; [31]), and a composite variable denoting whether participants reported probable Major Depressive Disorder, Bipolar Disorder, Dysthymia or Mild Depression was computed to assess presence of affective disorders.

2.2. Sleep assessment

Subjective sleep data were obtained from averaging one week of sleep diaries. During this time, one week of actigraphy was also collected. Subjective sleep variables included estimated total sleep time (S-TST), wake time after sleep onset (S-WASO), and number of naps (S-NAPS).

Actigraphic sleep recordings were made using an Actillume™ wrist actigraph worn for 1 week. All records were hand-scored for sleep, with the assistance of a validated algorithm [26]. The Actillume measured physical activity each second which was then averaged across one-minute epochs. Total sleep time (A-TST), sleep efficiency (A-SEFF), sleep acrophase (A-ACRO, the peak of a fitted 24-h cosine), and minutes asleep out of bed (A-NAPS) were computed using ACTION 3 software (Ambulatory Monitoring Inc., Ardsley, NY).

Table 1
Baseline subject characteristics.

Category	Variable	% Of respondents
Education		
	Did not go to school	0.2
	Grade school (1–4 yrs)	0.9
	Grade school (5–8 yrs)	0.9
	Some high school	4.1
	High school graduate	11.3
	Vocational school	10.2
	Some college or Associate degree	35.7
	College graduate or Baccalaureate degree	12.4
	Some college or professional school after college graduation	12.0
	Master's degree	11.7
	Doctoral degree	0.7
Family income		
	<$10,000	5.7
	$10,000–$19,999	13.1
	$20,000–$34,999	25.5
	$35,000–$49,999	20.5
	$50,000–$74,999	19.5
	$75,000–$99,999	6.9
	$100,000–$149,999	5.7
	$150,000+	3.1
BMI		
	Underweight (⩽18.4)	2.9
	Normal (18.5–26.9)	40.3
	Overweight (27.0–29.9)	34.0
	Obese (30.0–39.9)	19.6
	Morbidly obese (⩾40.0)	3.2

2.3. Diet assessment

Dietary nutrient variables were computed based on values from a semi-quantitative Food Frequency Questionnaire (FFQ), which asked about the portion size and frequency of consumption over the last three months of 122 foods or food groups, including vitamins and supplements [20]. This questionnaire also addressed other issues, such as added fats and food preparation. Nutrients were calculated using an automated script that referenced a database derived from the University of Minnesota Nutrition Coding Center [32]. The WHI FFQ was based on measures previously used in a number of clinical trials [33–35], has been validated previously [20] and has been reported in a number of studies from the WHI [36,37–39]. This measure yielded 88 distinct dietary variables.

2.4. Data analysis

To determine whether affective disorder should be included as a covariate, all subjective and objective sleep variables were evaluated with independent sample *t*-tests, comparing those with diagnosis to those without. A total of 29 participants were identified as having a present affective illness. When sleep variables were compared no significant differences were found (*p*-values ranging from 0.165 for actigraphic naps to 0.917 for sleep acrophase), except for subjective estimates of WASO ($t\,(423) = -2.9$, $p < 0.05$), though r^2 for this relationship, after adjusting for the other covariates (described below), was 0.016, indicating that presence of affective disorder explained 1.6% of the variance of subjective wake after sleep onset and no significant proportion of variance of any other variable. As subjective WASO was not significantly correlated with any variable, affective disorder was rejected as a covariate, suggesting that relationships between sleep and dietary variables are not explained by depression or other affective illnesses.

To evaluate sleep and nutrient variables, partial correlations (controlling for age, education, income, BMI, minutes of daily moderate/strenuous physical activity and daily grams food consumption) evaluated the relationships between subjective and objective sleep variables and 88 nutrient variables derived from the FFQ. Due to the large number of correlations, plots of *p*-values aided in establishing significance criterion, based on methods developed by Schweder and Spjotvoll [40]. The plot of ranked *p*-values was analyzed to determine the inflection point at which values deviate from the primary line. This deviation point is thought to represent the *p*-value at which significant findings are first observed. An alternative method, developed by Benjamini and Hochberg [41–43], was also used to derive a significance criterion. This method uses ranked *p*-values to determine the cutoff, at which point the Type-I error rate is below 0.05.

3. Results

3.1. Significance criterion

Examination of *p*-values established a $p = 0.004$ significance criterion among 602 correlations based on the Schweder and Spjotvoll criteria [40]; this identical criterion was established with the Benjamini and Hochberg method [41–43]. Thus, all correlations of $p < 0.004$ were considered statistically significant.

Significant partial correlations (controlling for age, education, income, exercise, BMI and total dietary grams) are reported in Table 2. Forty-nine of 63 reported correlations met the $p = 0.004$ significance cutoff, while 14 met a $p < 0.01$ cutoff. This latter threshold identified correlations that tended towards significance and may be of interest for further study, but did not achieve the significance level established for this study.