Cross-Sectional Relationship of Reported Fatigue to Obesity, Diet, and Physical Activity: Results From the Third National Health and Nutrition Examination Survey

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Study Objectives: Reported daytime fatigue may be influenced by modifiable risk factors. We hypothesized that daytime fatigue is associated with less-favorable lifestyle factors, including high body mass index, higher intake of dietary fat, and limited physical activity.

Design: Cross-sectional analysis.


Participants: Participants aged 20 to 59 years in the Third National Health and Nutrition Examination Survey.

Interventions: None.

Measurements and Results: We examined relationships between responses to the question, “Right now would you say you are feeling energetic, fresh, average, tired or exhausted?” and body mass index, waist circumference, leisure time physical activity, and macronutrient intake. Analyses included only people who reported getting their usual amount of sleep the night before the evaluation and controlled for age, sex, and ethnicity; 5.6%, 14.6%, 58.3%, 19.5%, and 2.0% reported that they felt “energetic,” “fresh,” “average,” “tired,” and “exhausted” respectively. There was a U-shaped association across the categories of fatigue for physical activity, body mass index, and waist circumference, with the healthiest lifestyle factors being associated with reporting feeling “fresh.” Relative to the fresh group, average, tired and exhausted participants were 1.6, 1.9, and 3.8 times more likely to report insufficient physical activity, all statistically different from the fresh group. This pattern was also observed for body mass index and waist circumference and persisted after adjustment for covariates and exclusion of individuals with depression.

Conclusions: In adults aged 20 to 59 years in the United States, self-reported fatigue is associated with higher body mass index, higher waist circumference, and a reduced likelihood of getting recommended levels of physical activity.

Keywords: Fatigue, depression, diet, nutrition, lifestyle, exercise

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In the past 2 decades, sleep length for the general population of the United States has decreased from 8 to 8.9 hours a night to 7 to 7.9 hours per night. Only about a third of Americans achieve 8 or more hours of sleep a night, and an equal number get 6 or fewer hours of sleep a night. In an effort to evaluate consequences of this reduction in sleep time, several investigators have explored the relationship between sleep duration and outcomes. Sleep duration is related to morbidity and mortality, with the lowest risk observed for those sleeping 7 or 8 hours a night and increased risk at both extremes of the distribution of sleep duration. For example, Ayas and colleagues showed that women sleeping fewer than 6 or more than 9 hours a night were at increased risk for coronary events and mortality, results that confirmed earlier work by Kripke.

Sleep reduction has also been associated with metabolic derangements. Among healthy individuals with experimentally induced sleep deprivation, cortisol levels and caloric intake increase and glucose tolerance and leptin levels decrease. Ayas showed an association between short sleep duration and diabetes, and von Kries demonstrated that prevalence of obesity is inversely associated with duration of sleep, even in young children, controlling for other risk factors. Recently, in a 13-year observational prospective study of a well-defined cohort, Halser demonstrated an inverse “dose response” relationship between increases in body mass index (BMI) and sleep duration at all time points, although the dose-response curve was fairly flat between 5 and 9 hours of sleep. The relationship between sleep duration and weight weakened at the age of 40 years, which suggests that behavior in early life builds a foundation for health in later years.

Among the problems with evaluating the relationship between sleep duration and metabolic consequences is that sleepiness or fatigue may mediate the adverse consequences of inappropriate sleep durations (rather than a direct effect of the sleep curtailment itself) and that sleepiness and fatigue are difficult to differentiate from each other. For example, individuals who do not get enough sleep or sleep that is of high quality may feel fatigued or unrefreshed. They might curtail physical activity or consume more food.
calories in an attempt to conserve or to boost energy levels.

The purpose of this study is to determine if categories of reported daytime fatigue are associated with less-favorable lifestyle factors. We hypothesized that, among people who report a typical night's rest the previous night, reported fatigue the following day is associated with higher BMI and waist circumference measurements, greater intake of dietary fat, and less leisure-time activity compared with those who do not report feeling tired.

METHODS

Data and Study Sample

The Third National Health and Nutrition Examination Survey (NHANES III) was conducted from 1988 to 1994 by the National Center for Health Statistics, Centers for Disease Control and Prevention. The survey was designed to generate nationally representative data describing the civilian, noninstitutionalized United States population aged 2 months and older. The examination consisted of a home interview and a detailed clinical examination performed in a mobile examination center. A total of 18,885 adults 20 years of age and older responded to the household adult and family questionnaires.

The objective of selecting the analysis sample for this report was to study the relationship between a subjective measure of fatigue and several outcomes among persons reporting typical sleep the previous night. We focused our analyses on persons who reported having a typical night’s sleep on the night prior to survey participation in order to avoid drawing conclusions that may be due to atypical sleep experience. Of the adults completing the household questionnaire, 5662 randomly selected individuals aged 20 to 59 years received the central nervous system (CNS) examination, which included sleep-related questions as part of the protocol.

Participants for this report were therefore selected from among participants completing the CNS protocol. Of the 5662 participants completing the CNS protocol, 518 did not answer the question, “How much sleep did you get last night? Would you say about the usual amount, less than usual, or more than usual?” We excluded these individuals from the analysis, since we were unable to determine if the previous night’s sleep in this group was reported as typical. We also excluded 2013 participants who reported sleeping less (n = 1,552) or more (n = 461) than the usual amount the previous night. Compared with those with the usual amount of sleep the previous night, those with less than the usual amount of sleep were less likely to report feeling “energized or fresh,” whereas those with more than the usual amount of sleep were more likely to report feeling “energized or fresh.” We chose to exclude these individuals in order to eliminate the effect of this acute exposure on the main independent variable of interest (self-reported fatigue). One additional person was excluded because of a missing response for the question asking about level of fatigue. A study sample of 3130 adults aged 20 to 59 years (55% of those who received the CNS protocol) reported having experienced typical sleep on the night prior to the examination and provided a response to this question. These individuals constitute the analysis sample for this report.

Assessment of Fatigue

To assess fatigue, participants were asked “Right now would you say you are feeling energetic, fresh, average, tired or exhausted?”

Mental Health Questionnaire

The NHANES III survey contains an extensive mental health component, including the depression and mania modules from the Diagnostic Interview Schedule (DIS), which were originally developed for the National Institute of Mental Health Epidemiologic Catchment Area program. Trained interviewers administered the DIS questions to participants aged 15 to 39 years. Depression was diagnosed based on the third edition of the Diagnostic and Statistical Manual of Mental Disorders.

We used the depression data to construct a subsample of people with typical sleep with which we could conduct sensitivity analyses excluding persons with depression. Of the 3130 participants with typical sleep on the night prior to the interview, 1837 individuals aged 20 to 39 years received the depression questionnaire. Of these, 113 were found to have major depression. Thus, data are available for 1724 participants aged 20 to 39 years who were known to be free of depression and who reported typical sleep the previous night. These individuals represent 55% (1724/3130) of all participants with typical sleep, and they constitute the sensitivity analysis sample.

Anthropometric Measures

Body measurements were recorded by a trained examiner. Weight was measured in kilograms, and standing height and waist circumference were recorded in centimeters. BMI was computed from weight and standing height using the following formula: weight (kg)/height (m)^2.

Assessment of Macronutrient Intake by 24-hour Recall

Dietary interviews were administered to participants by a trained dietary interviewer. In a standard 24-hour recall, respondents reported all foods consumed for the previous 24-hour time period (midnight to midnight). Percentages of daily calories from carbohydrates, protein, and fat were calculated as follows: percentage of kcal from protein=(grams protein*4 kcal/gram)/total kcal)*100; percentage of kcal from carbohydrates=(grams carbohydrates*4 kcal/gram)/total kcal)*100; percentage of kcal from fat=(grams of fat*9 kcal/gram)/total kcal)*100.

Assessment of Physical Activity Levels and Determination of Recommended Level of Physical Activity

Participants were asked how frequently they performed specified leisure-time exercise or physical activities, as well as “other” physically active exercises or hobbies, in the past month. Based on this self-reported information, participants were classified into 1 of 3 groups: inactive, insufficient activity, or recommended activity. Participants were classified as inactive if they did not report engaging in any of the following activities during the previous month: walking, jogging, bike riding, swimming, aerobics, dancing, calisthenics, gardening, lifting weights, or other physical activity outside of their occupation. Physical activity was classified as moderate or vigorous intensity based on metabolic equivalent intensity levels. Participants were considered to fulfill national recommendations for physical activity if they reported 5 or more episodes per week of moderate-intensity physical activity or 3
or more episodes per week of vigorous-intensity physical activity.16,17 Those reporting some physical activity during the preceding month but not at the recommended levels were classified as obtaining insufficient physical activity.

Statistical Analysis

The objective of this report is to quantify the cross-sectional relationship of self-reported categories of fatigue to BMI, waist circumference, macronutrient intake, and report of recommended level of physical activity. We display unadjusted cross-sectional relationships between fatigue levels and each outcome by plotting means and proportions as appropriate. To determine the effect of fatigue categories on each outcome adjusted for age, sex, and ethnicity (all factors postulated to be associated both with sleep and each outcome), we used regression models to calculate β coefficients associated with each category relative to the reference group.

For the purposes of this report, we selected “fresh” as the reference group of interest. This decision was based on several factors. First, it is intuitively appealing to compare other levels to “fresh,” since, in a clinical setting, one would not advise a patient to work toward feeling “average” or “exhausted.” We did not choose “energetic” as the reference group largely because the number of participants in that group was relatively small and because this may not be a practical clinical target.

For the continuously distributed dependent variables (BMI, waist circumference, and nutrients) we used the linear-regression model to calculate β coefficients associated with each level of the fatigue categories, relative to the “fresh” category. Since the distribution of macronutrient intake is associated with obesity, we ran the macronutrient models with and without adjustment for BMI to determine if the strength of association of the fatigue variables changed depending on whether BMI was considered in the model or not.

For recommended level of physical activity, which is a binary response, we used the logistic-regression model to calculate β coefficients for each fatigue category relative to “fresh” representing the log odds ratio associated with not having recommended levels of physical activity. Once again, since BMI may confound the association between fatigue and physical activity, we ran the models with and without BMI.

Because this is a cross-sectional survey and causation cannot be determined, fatigue could have been modeled as either the dependent or independent variable. The regression models are constructed as they are to allow for the inclusion of 4 dummy variables (representing the 5 fatigue levels) as independent variables. This allows us to quantify the cross-sectional association between these categories and the outcomes, which is the objective of the study.

We first conducted all analyses on the sample of 3130 participants aged 20 to 59 years who reported having a typical night of sleep prior to the NHANES exam. To ensure that depression was not influencing our initial results, we reran all analyses on the subsample of 1724 participants aged 20 to 39 years who had mental health information and were known to be free of major depression.

Two “dummy” variables were created to examine race (black vs white and Mexican American vs white) and were added to the regression models. White was therefore used as the reference group.

Statistical analyses were conducted using the SAS and SUDAAN statistical software packages (SAS Institute, Cary NC, and Research Triangle Institute, Research Triangle Park, NC). Only results from SUDAAN analyses are presented because these take into account the complex sampling and design of the NHANES surveys. The final examination weights for this sample were first adjusted for selection of a sample among adults (20-59 years) and poststratified to unpublished Current Population Survey 1990 (Phase 1) and 1993 (Phase 2) population control estimates of the United States population adjusted for undercount in the final step.18

RESULTS

Table 1 summarizes selection of the analysis sample (n = 3130) and the sensitivity analysis sample (n = 1724) from among the 5662 persons who were evaluated as part of the NHANES III CNS examination. The analysis sample represents 55% of the total number of persons who participated in the CNS exam, and the sensitivity analysis sample represents 30% of the latter group.

Table 2 summarizes sleep levels, as well as demographic, anthropometric, dietary, and physical activity levels data according to whether participants who had the CNS protocol were included (n = 3130) or excluded (n = 2532) from the analysis sample. Among United States adults aged 30 to 59 years reporting a typical night’s sleep the night before, the proportions reporting that they felt “energetic,” “fresh,” “average,” “tired,” and “exhausted” the next day were 5.6%, 14.6%, 58.3%, 19.5%, and 2.0%, respectively.

Persons included in the study sample had a somewhat different distribution of reported fatigue than did excluded persons, with a higher proportion of persons reporting feeling “average” and a lower proportion feeling “tired.” The table also suggests that included persons were more likely to be white and were slightly older than excluded persons. No differences between included and excluded persons were observed for sex, BMI, or the dietary variables. Table 2 also provides a comparison between the analysis sample of 3130 and the sensitivity subsample of 1724. As expected from the specifications of the NHANES III protocol, mean age of the sensitivity-analysis subsample was considerably lower than that for the analysis sample and waist circumference and BMI were both slightly lower. Few other differences were noted. We do not present tests of significance for comparisons between the full analysis sample and the sensitivity sample because one group is a subset of the other.
We created plots similar to those in Figures 1 and 2 for percent across categories. Repetition of this analysis in the sensitivity sample of 1724 yielded an identical U-shaped pattern exhausted categories. Repetition of this analysis in the sensitivity sample yielded a similar pattern, but results were not significant due the reduced power associated with the smaller sample size. A U-shaped association was also observed for waist circumference, adjusted for covariates. Results of the sensitivity analysis for waist circumference were similar to those for BMI. Of the 3130 participants, 1601 were examined in the afternoon or evening, and 1529 were examined in the morning. Inclusion of a time of day of interview variable in the regression models did not materially change the odds ratios compared with the age-, sex-, and race-adjusted model. Sensitivity analyses of physical activity conducted among the 1724 participants included (n = 3130) and excluded (n = 2532) in the analysis.

Table 3 summarizes results of both linear and logistic regression analyses focusing on the age-, sex-, and race-adjusted associations of the fatigue categories with BMI, waist circumference, and odds of not having recommended levels of physical activity. Overall, results of the adjusted models closely mirrored those from initial unadjusted analyses with respect to the U-shaped association across categories. Differences in mean BMI were not significant across the categories. Analysis of BMI in the sensitivity sample yielded a similar pattern, but results were not significant due the reduced power associated with the smaller sample size. A U-shaped association was also observed for waist circumference, adjusted for covariates. Results of the sensitivity analysis for waist circumference were similar to those for BMI. Of the 3130 participants, 1601 were examined in the afternoon or evening, and 1529 were examined in the morning. Inclusion of a time of day of interview variable in the regression models did not significantly change the magnitude or direction of the β coefficients for the sleepcategory variables.

The effect of fatigue on the adjusted odds of not getting recommended levels of physical activity were striking: Compared with the fresh group, exhausted, tired, and average participants were 3.8, 1.9, and 1.6 times more likely to not get the recommended level of physical activity, findings that were statistically different from the fresh group. Curiously, the energetic group was also more likely not to get recommended activity. Additional adjustment of this model for BMI did not materially change the odds ratios compared with the age-, sex-, and race-adjusted model. Sensitivity analyses of physical activity conducted among the 1724 participants yielded a similar pattern, with odds ratios strengthened somewhat in the exhausted group.

**DISCUSSION**

The primary findings of this analysis are U-shaped relation-
The relationship between sleep duration and quality, appetite regulation, metabolic function, and obesity is complex. Leptin is believed to downregulate appetite, and ghrelin is believed to stimulate it. Early well-controlled laboratory studies demonstrated that both acute and chronic partial sleep deprivation can affect levels of appetite-regulating hormones and hunger. In well-controlled laboratory studies of small numbers of healthy people, sleep deprivation has been demonstrated to result in increased cortisol levels, worsened glucose tolerance, reduced leptin levels, increased hunger, and increased caloric intake compared with when the people are rested.

More recently, population-based studies have also demonstrated that reduced sleep is associated with overweight and obesity. A recent study of 1024 people from the Wisconsin Sleep Cohort Study demonstrated reduced levels of leptin, increased levels of ghrelin, and increased BMI with short sleep. The relationship among short sleep, metabolic dysfunction, and obesity is a consistent finding in the literature and appears to begin in childhood. Importantly, the increase in obesity in this country has paralleled a decrease in the average amount of nightly sleep obtained by Americans.

In studies of sleep duration and metabolic problems, investigators have emphasized adverse effects of limited sleep. However, several of the investigations of sleep duration and diverse health outcomes have demonstrated U-shaped relationships such as we observed in this study. For example, the Wisconsin Sleep Cohort Study showed a U-shaped relationship between BMI and reported sleep time, with BMI rising on either side of an average nightly sleep time of 7.7 hours. In an earlier survey of 1.1 million people, Kripke reported a U-shaped relationship between BMI and self-reported habitual sleep duration, with increasing BMI on either side of 7 hours of sleep. Thus, this surrogate measure of sleep showed a U-shaped association in a manner that is highly consistent with previous research.

Sleep duration has also been shown to have a U-shaped relationship with morbidity and mortality, with the lowest risk being seen for those sleeping 7 or 8 hours a night and increasing risk for either ends of the “U.” For example, Ayas showed that women sleeping fewer than 6 or more than 9 hours a night were at increased risk of coronary events and mortality. Thus, while investigators and editorials proclaim the importance of adequate sleep, it might be prudent to note that too much sleep may also be associated with risk.

We found that those reporting the least amount of exercise were more likely to report feeling exhausted and that those reporting the most exercise were more likely to feel fresh. Since the NHANES survey is cross-sectional, it is not possible to determine causality; whereas physical activity has been shown to enhance sleep quality in older humans, and in mice, it has not consistently been shown to be related to sleep quality. In a report of a small number of patients with sleep apnea, higher levels of physical activity were associated with less fatigue and better scores on the SF-36 and Profile of Mood States measures. Earlier work from the Wisconsin Sleep Cohort Study demonstrated that those who slept more, exercised less. Clearly, the relationships among sleep, exercise, and fatigue are complex, but it is probably safe to say that the amount of sleep alone is a simplistic and inadequate measure of sleep’s “effectiveness.”

There are several limitations to this investigation. First, data available for analysis are limited to those measures collected in NHANES. The NHANES surveys are designed to provide a general overview of the health of Americans and, therefore, do not contain specialized protocols such as polysomnograms or other measurements or detailed sleep-related questionnaires that would have been ideal in this setting. Nonetheless, our NHANES analyses benefit from broad generalizability despite the absence of detailed quantitative measures of sleep. A second limitation concerns selection of the analysis sample. Because questions related to self-reported fatigue were obtained from the CNS protocol in NHANES, our sample was limited to those persons who were randomly selected to receive that protocol. We used data from a larger age range available in NHANES, this report could have been strengthened by age-stratified analyses of fatigue and behavioral factors. However, despite the relatively limited age range, our findings can be considered generalizable to United States adults aged 20 to 59 years reporting a typical night’s sleep the previous night. This degree of generalizability is not avail-

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Table 3—Summary of Linear and Logistic Regression Analyses, n=3130

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<thead>
<tr>
<th></th>
<th>Linear Regression</th>
<th>Logistic Regression</th>
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<tbody>
<tr>
<td></td>
<td>BMI (95% CI)</td>
<td>Waist circumference, cm (95% CI)</td>
</tr>
<tr>
<td>Energetic</td>
<td>0.82 (-0.22 – 1.85)</td>
<td>1.91 (-0.92 – 4.74)</td>
</tr>
<tr>
<td>Fresh</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(reference)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>0.42 (-0.27 – 1.11)</td>
<td>0.81 (-1.18 – 2.80)</td>
</tr>
<tr>
<td>Tired</td>
<td>1.31 (0.32 – 2.30)</td>
<td>3.37 (0.74 – 5.99)</td>
</tr>
<tr>
<td>Exhausted</td>
<td>2.13 (-0.03 – 4.30)</td>
<td>7.53 (2.35 – 12.70)</td>
</tr>
</tbody>
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Models adjusted for age, sex, and ethnicity. BMI refers to body mass index; CI, confidence interval; OR, odds ratio.
able in other smaller studies, despite their more sophisticated sleep protocols. Moreover, the availability of depression data for the subset of the sample aged 20 to 39 years permitted us to construct a sensitivity-analysis sample, which revealed no effect of depression on our initial observations. Once again, although there are notable weaknesses of the NHANES surveys in terms of the complexity of available sleep data, the diversity of protocols and public health implications offered by this data source should not be underestimated. Indeed, our analyses strongly suggest a persistent association between self-report of fatigue and a number of modifiable risk factors. At minimum, these data add to the growing body of literature suggesting a connection between sleep and common obesity-associated diseases. Another limitation of extraction of findings from large databases such as NHANES is that measurement of confounders may not be optimally precise or comprehensive. It is possible that behavioral issues such as alcohol or tobacco use may have affected the reported level of energy or the BMI of the participants.

Finally, the U-shaped association between fatigue category and behavioral factors raises a number of important questions related to perception of being tired during the day and the association between perceived fatigue and actual sleep quality and factors such as somnogenic cytokines. For example, Vgontzas et al have demonstrated that even modest sleep restriction results in sleepiness, impaired psychomotor performance, and increased levels of proinflammatory cytokines. We believe that findings from this large, representative national data set generally support the hypothesis that self-reported fatigue, or the poor sleep quality and/or duration that may be associated with self-reported fatigue, is associated with unfavorable but modifiable behavioral and anthropometric factors.

In summary, among United States adults aged 20 to 59 years who report having had a typical night’s sleep the night before completing the questionnaire, report of feeling average, tired, or exhausted is associated with higher BMI and waist circumference and reduced odds of getting recommended levels of physical activity, compared with those who report feeling fresh. By design, our cross-sectional data cannot show that poor sleep is a cause of these unfavorable characteristics. However, our data support a growing body of evidence linking poor sleep with clinical and behavioral factors that are known to enhance the risk of chronic illnesses related to obesity and sedentary lifestyle.

ACKNOWLEDGEMENT

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REFERENCES

18. NHANES III Analytic and Reporting Guidelines, United States Department of Health and Human Services; 1996.