DIET QUALITY AND EVENING SNACKING IN RELATION TO SLEEP DURATION AND QUALITY AMONG WOMEN WITH YOUNG CHILDREN

A Dissertation Presented

By

RUI XIAO

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ABSTRACT

Background: Mothers' diets impact their health and the health of their children, but diet quality is suboptimal among women with young children. Evening snacking among women with young children, especially consumption of high-calorie, high-carbohydrate snacks, may impact overall diet quality and glucose metabolism. Short sleep duration and poor sleep quality may be potential risk factors. We examined whether sleep duration and poor sleep quality were associated with diet quality and evening snacking among women with young children.

Methods: Data were from the National Health and Nutrition Examination Survey (NHANES) 2005-2012, nationally representative cross-sectional surveys of non-institutionalized U.S. population. Eligible participants were non-pregnant women aged 20-44 years within 5 years of childbirth who completed two 24-hour dietary recalls and completed questions on sleep duration and quality.

Results: Among US women with young children, sleep duration was not associated with diet quality. However, overall sleep quality was associated with poorer diet quality. Short sleep duration was not associated with the consumption of neither evening snacks, nor energy intake from or nutrient consumption of evening snacks.

Conclusion: The findings of this dissertation provide information useful for informing the direction of future research of dietary quality and eating behaviors of U.S. women with young children. Studies are needed to explore whether improvement in sleep quality may improve diet quality among women with young children, which has the potential to

improve both maternal and children’s health. Research may be better focused on identifying other psychosocial and behavioral risk factors for unhealthy dietary behaviors among US women with young children.

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Rui S. Xiao, Tiffany A. Moore Simas, Sherry L. Pagoto, Sharina D. Person, Milagros C. Rosal, Molly E. Waring. Sleep Duration and Diet Quality among Women within 5 Years of Childbirth in the United States. Maternal and Child Health Journal.

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CHAPTER I

INTRODUCTION

Unhealthy diet is a major cause of chronic disease, yet many US adults consume diets that do not meet dietary recommendations. In particular, intake of whole grains and fiber,[1] and fruit and vegetables[2] may reduce the risk of chronic diseases, including obesity, type 2 diabetes, and cardiovascular disease. On the other hand, intake of saturated fats,[3] sodium,[4] and sugar-sweetened beverages[5,6] may increase chronic disease risk. In recent years, methods for measuring diet quality have evolved. Although the examination of individual foods and nutrients has been useful, an examination of diet quality provides a holistic view of the total diet. Diet quality involves the assessment of both the components and variety of the entire diet. It measures how closely people's diet align with national dietary guidelines and how diverse the variety of healthy choices is within core food groups.[7] The Dietary Guidelines for Americans have been jointly published by the U.S. Department of Health and Human Services, and the U.S. Department of Agriculture every five years from 1980.[8] Adhering to dietary guidelines is associated with significantly decreased risk of chronic diseases[9–11] and mortality.[12] The current guideline, the Dietary Guidelines for Americans 2010, emphasizes three major goals: balancing calories with physical activity to manage weight, consuming more of certain food and nutrients, such as fruit, vegetables, whole grains, fat-free and low-fat dairy products, and seafood, and consuming fewer foods with sodium, saturated fat, trans fats, cholesterol, added sugars, and refined grains.[8] Although the quality of the US diet improved modestly from 1999 to 2010,[13] it remains far from optimal[14] and there is still room for improvement.

In addition to diet quality, unhealthy eating habits, including evening snacking, are also important risk factors for poor cardiometabolic health. Healthy eating habits are important for chronic disease prevention.[15] Recently, snacking has garnered significant interests as a dietary pattern that may be amenable to targeted interventions. Over the past 30 years, the prevalence of snacking has increased from 71% to 97% among US adults, and calories from snacks have risen from 18% to 24% of total daily energy intake over this period.[16] The timing and composition of snacks are important for energy balance and cardiometabolic health.[17–20] Evening snacking, defined as snacking occurring between dinner and bedtime,[20] is of particular interest. Over the past few years, health and weight conscious individuals are recommended to limit and/or avoid food in the hours close to nighttime sleep because it would negatively affect health and energy balance.[21] In healthy normal weight men, the postprandial metabolic response to identical meals changes throughout the day. When identical meals (~544kcals, 15% protein, 35% fat, 50% carbohydrate) are consumed either in the morning, afternoon, or at night, the thermic response to that meal appears to be the lowest when the meals is consumed at night.[22] Meal satiety also varies with time of the day and that food intake during the night is less satiating and leads to greater daily calorie intake compared to food consumed in the morning hours.[23] Consuming protein or carbohydrates in the late evening has been found to negatively affect insulin levels,[24] and is associated with greater glucose concentration and impaired ability of insulin secretion to compensate for reduced insulin sensitivity.[19] Thus, evening snacking, especially consumption of high-calorie, high-carbohydrate snacks, is an important dietary target.

Women with young children compose a population for whom high diet quality and healthy eating habits are important, yet are suboptimal. The transition to motherhood is a period of social, psychosocial, behavioral, and biological changes in women's lives. From the life course perspectives, adaptations to role transitions may lead to changes in health behaviors. Although women make changes to healthy food choices during pregnancy, such behavioral changes are often not maintained after childbirth.[25,26] Diet quality is suboptimal among women with young children, with one study estimating that only 9% of overweight and obese women with young children meeting the national recommendations of having a good quality diet.[27] Specifically, women are not in compliance with guidelines related to grains, vegetables, fruit, dairy, sodium, fat intake, and dietary variety.[28] While there are not quantitative studies to our knowledge that report the prevalence of evening snacking among U.S. women with young children, qualitative studies among women with young children indicate that many women consume evening snacks after their children go to bed which often include unhealthy foods,[29] which suggests that the evening snacking may be common in this population. As children's food habits initiate at a young age,[30] women's diet quality and eating habits may influence and shape their children's eating patterns. Identifying risk factors for poor diet quality and unhealthy eating habits among women with young children may improve eating habits of their offspring and subsequently combat childhood obesity.[31] Thus, understanding what and how women with young children eat is important for maternal and child health. One potentially modifiable risk factor for poor diet quality and suboptimal eating habits among women with young children is impaired sleep.

Impaired sleep has been linked with poor diet quality and greater evening snacking among adults generally,[32–34] and is prevalent among women with young children.[35,36] Sleep deprivation is associated with poorer diet quality among young women.[37] Literature suggests that both short or long sleep duration may be associated with misalignment with the circadian rhythm,[38] which may lead to lower circulating leptin levels and greater tendancy to overeat. In lab studies, experimentally shortened sleep duration led to greater energy intake particularly in the evening of the following day, largely due to increased snacking of foods with higher carbohydrate content.[33] Experimentally-induced sleep deprivation has also been associated with greater consumption of carbohydrates, protein, and fiber after dinner.[39] Poor sleep quality is associated with decreases in plasma levels of leptin and increases in serum levels of ghrelin,[34,40] which may impact appetite regulation,[41] and stimulate the consumption of energy-dense foods, [42,43] and consequently contribute to poorer diet quality [34,37] and higher energy intake.[34,44] Short sleep duration (<7 hours per night versus, adequate sleep duration [7-8 hours per night] or long sleep duration [>8 hours per night])[45] and poor sleep quality (characterized by nighttime awakening and sleep fragmentation) are common among women with infants and young children.[35,36,46–48] A recent study of working moms indicated that each child under the age of two was associated with an average of 13 fewer minutes of parental sleep per day, and each child aged 2-5 years was associated with 9 fewer minutes of sleep.[49] Parents of children aged 2 years or older were also more likely to have daytime sleepiness.[49] Four in ten (42%) women reported rarely or never having a good night's sleep and 84% reported experiencing sleep problems at least a few nights per week up to 6 months following delivery.[36] As newborns start sleeping through the night on average at 8 weeks of age,[50] maternal nocturnal wakening decreases gradually,[51] and sleep quality may improve.[52] However, 17.5% of women with young children are still dissatisfied with their sleep.[48] Despite the strong link between maternal diet quality and eating behaviors with children's diet quality and eating behaviors and childhood obesity,[27] and the high prevalence of impaired sleep among women with young children,[35] limited research has examined the association between sleep duration and sleep quality with diet quality and evening snacking. We examined whether impaired sleep is associated with poor diet quality or greater evening snacking among women with young children.

Specific Aims

The overarching goal of this dissertation is to examine the association between sleep duration and sleep quality with diet quality and evening snacking among U.S.women with young children. We used data from a nationally representative National Health and Nutrition Examination Survey (NHANES) to examine three Specific Aims.

Aim 1: To examine the association between sleep duration and diet quality among women with young children.

H1: Women with short sleep duration will have poorer diet quality compared to women with adequate sleep duration.

H2: Women with long sleep duration will have poorer diet quality compared to women with adequate sleep duration.

Aim 2: To examine the association between sleep quality and diet quality among women with young children.

H3: Women with poor quality sleep will have poorer diet quality compared to women with adequate sleep quality.

Aim 3: To examine the association between sleep duration and evening snacking among women with young children.

H4: Women with short sleep duration will be more likely to report evening snacking compared to women with adequate sleep duration.

H5: Among women who consume evening snacks, women with short sleep duration will consume more energy, total fat, and carbohydrate, and less protein and fiber from evening snacks compared to women with adequate sleep duration.

CHAPTER II

SLEEP DURATION AND DIET QUALITY AMONG WOMEN WITH YOUNG CHILDREN IN THE UNITED STATES

Abstract

Objective: Diet quality is suboptimal among U.S. women with young children. Previous research has observed a U-shaped association between sleep duration and diet such that individuals with short or long sleep duration had poorer diet quality and unhealthy eating behaviors compared to those with adequate sleep duration. We examined diet quality in relation to sleep duration among U.S. women within 5 years of childbirth.

Methods: Data were from non-pregnant women aged 20-44 years within 5 years of childbirth who completed two 24-hour dietary recalls (N=1012) in the National Health and Nutrition Examination Survey (NHANES) 2005-2012. Self-reported weekday/workday sleep duration was categorized as short (<7 hours), adequate (7-8 hours), or long (>8 hours). The Healthy Eating Index (HEI-2010, range: 0-100) estimated overall and components of diet quality. Multivariable-adjusted linear regression models estimated the association between sleep duration and diet quality, adjusting for age, race/ethnicity, and education level.

Results: Thirty-five percent of women reported short, 56.1% adequate, and 8.6% long sleep duration. The average diet quality total score was 47.3 out of 100. Neither short sleep duration (β=-1.9, 95% CI: -4.7 to 0.9) nor long sleep duration was associated with diet quality (β = -2.7, 95% CI: -6.8 to 1.4).

Conclusions: Sleep duration was not associated with diet quality among U.S. women with young children. Future studies are needed to explore other behavioral or psychosocial factors, which may impact maternal diet quality, including sleep quality.

Introduction

Diet quality assessment is a measure of how individuals' diets aligns with national recommendations.[7] High diet quality reduces risk of several chronic diseases [9,11] and mortality.[12] In particular, the intake of whole grains and fiber,[1] and fruit and vegetables[2] reduce chronic disease risk, while the intake of saturated fat,[3] sodium,[4] and sugar-sweetened beverages[6] may increase disease risk.

Diet quality is particularly important for women with young children. Food preferences and eating habits are established at a young age,[53] and women's food preferences influence their children's preferences, and the quality of their diet is a significant contributor to their children's diet quality.[27,53] However, only 9% of overweight and obese women with preschool-aged children have a diet quality score of at least 80/100 meeting national recommendations.[27] Understanding and intervening upon what women with young children eat has the potential to impact the long-term health of both women and their children.

Sleep duration may be a risk factor for poor diet quality. A recent study observed a U-shaped association between sleep duration and eating behaviors among middle-aged and older women; women with short or long sleep duration were more likely to eat during unconventional hours and replace meals with snacks than women with adequate sleep duration.[32] Sleep deprivation occurs frequently among women with young children[35] and short sleep duration has been associated with poor diet quality among young women,[37] including skipping meals, higher energy intake from snacks and beverages, and greater sugar consumption.[45] Women with long and short sleep duration report similar eating patterns, which are less healthy than women with adequate sleep.[32]

No published studies have examined the association between sleep duration and diet quality among women with young children. This information is essential to inform lifestyle interventions that target challenges to healthy eating in this population. The purpose of this study was to examine the association between sleep duration and diet quality among U.S. women within 5 years of childbirth. We hypothesized that women with either short or long sleep duration would have poorer diet quality compared to women with adequate sleep duration.

Methods

Study design and participants

The National Health and Nutrition Examination Surveys (NHANES) are cross-sectional surveys including nationally representative samples of non-institutionalized Americans. NHANES employs a complex multi-stage probability cluster design.[54] Participants were interviewed by trained, mostly bilingual, interviewers at their homes or at a Mobile Examination Center (MEC) and were followed-up on the phone. Details of the NHANES sampling methodology and procedures have previously been published.[54] Since information on sleep duration was first collected in 2005-2006, we combined four waves of NHANES data: 2005-2006, 2007-2008, 2009-2010, and 2011-2012. Our analytic sample included non-pregnant women aged 20 to 44 years who delivered their youngest child within the past 5 years and completed two dietary recalls. We limited the study sample to women aged 20 to 44 years because reproductive data including results of the pregnancy test were publicly available only for women within this age range. The University of Massachusetts Medical School Institutional Review Board deemed this study exempt from human subject research oversight.

Sleep duration

Participants were asked: "How much sleep do you usually get at night on weekdays or workdays?" Their sleep duration was reported as an integer number. NHANES coded women who reported having 12 hours or more sleep as having 12 hours of sleep. We categorized the continuous variable of sleep duration as short (<7 hours), adequate (7-8 hours), and long (>8 hours), consistent with previous studies.[45] Participants with missing information on sleep duration were excluded from analyses.

Diet quality

Participants completed two 24-hour dietary recalls, the first at the MEC, and the second via phone 3-10 days later. During both interviews, participants listed types and amounts of foods and beverages they consumed from midnight to midnight on the previous day. We used the Healthy Eating Index (HEI)-2010, a valid and reliable measure of diet quality index that assesses adherence to the Dietary Guidelines for Americans 2010.[14] It includes 12 components, resulting in a total score of 100 points, where a higher score indicates better compliance with dietary guidelines and better overall diet quality. Nine components assess adequacy of the diet, where higher scores indicate greater consumption: total fruit (including fruit juice), whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and the ratio of poly- and monounsaturated fatty acids to saturated fatty acids. For the other three dietary components (refined grains, sodium, and empty calories from solid fats, alcohol, and added sugars), higher scores indicate lower consumption. Intakes between the minimum and maximum standards were scored proportionately. We used average intake across the two recalls to calculate HEI-2010 scores using SAS code available at http://www.cnpp.usda.gov/healthy-eating-index-support-files-07-08.

Potential confounders

We considered age, race/ethnicity, education level, marital status, poverty income ratio (PIR), weight status, years after recent childbirth, smoking status, physical activity level, and diagnoses of several chronic diseases (e.g., hypertension, diabetes, and gestational diabetes) as potential confounders. Except for height and weight, these data were self-reported during the interview. We categorized race/ethnicity as non-Hispanic White, non-Hispanic Black, Mexican-American/Hispanic, and other race/ethnicity (including multi-racial). We categorized education level as less than high school, high school graduate/GED, some college/Associate’s degree, and college graduate or higher. We categorized marital status as married or living with partner, widowed/separated/divorced, and never married. Household poverty income ratio (PIR) is the ratio of household income to poverty threshold for a household of that size and was categorized as <100% Federal Poverty Level (FPL), 100-300% FPL, and >300% FPL. Body mass index (BMI; kg/m^2) calculated from measured height and weight was categorized as underweight ($<18.5\ kg/m^2$), normal weight ($18.5 \leq BMI < 25\ kg/m^2$), overweight ($25.0 \leq BMI < 30\ kg/m^2$), and obese ($BMI \geq 30\ kg/m^2$). Participants were asked “Have you smoked at least 100 cigarettes in your entire life?” and those who replied “no” were classified as never smokers. Women who replied “yes” were asked, “Do you now smoke cigarettes?” Those who responded with “every day” or “on some days” were classified as current smokers. Those who replied “no” were classified as former smokers. Participants were asked about the frequency and duration of various physical activities over the past 30 days or in a typical week. Participants were categorized as following physical activity guidelines if they engaged in 150 minutes or more of moderate-intensity activities per week. Participants reported whether they had been diagnosed with several chronic diseases, including hypertension, diabetes and gestational diabetes mellitus.

Statistical analyses

All statistical analyses accounted for sample weights and the complex survey design; results are representative of childbearing women aged 20-44 years nationally. As recommended in the NHANES analytic guidelines (http://www.cdc.gov/nchs/nhanes/analytic_guidelines.htm), we created a combined 8-

year weight by assigning one-fourth of the 2-year weight for each survey cycle (2005-06, 2007-08, 2009-10, and 2011-12).

We compared the characteristics of women within 5 years of childbirth in relation to sleep duration using chi-square tests for categorical variables and ANOVA for continuous variables. We used a linear regression model to estimate the association between sleep duration and overall diet quality, with women with adequate sleep duration (7-8 hours) as the reference group. For each potential confounder, we used a complete case sample excluding participants missing information on that confounder and examined whether it was associated with overall diet quality with a p value of < 0.25. Potential confounders were included and retained in the adjusted model if the regression coefficient changed appreciably (i.e., by about 10%). We constructed an final analytic sample including eligible women without missing information on covariates included in adjusted models; all results presented use this final analytic sample. We constructed multivariable-adjusted linear regression models to estimate the association between sleep duration and each HEI-2010 component score, adjusting for the same set of covariates for consistency of interpretation.

We conducted two sensitivity analyses. First, because the Healthy People 2020 suggests sleep duration of a minimum of 8 hours for those aged 18 to 21 years as adequate,[55] we categorized short sleep duration as <8 hours among women aged 20 or 21 years old in our sample, and repeated our analyses of diet quality in relation to sleep duration using this alternative definition. Second, altered sleep duration (either short or long sleep) is common among adults diagnosed with major depressive disorders,[52] and in fact, is a symptom considered in the diagnosis of depression.[56] Depressive symptoms were assessed at the MEC using the Patient Health Questionnaire (PHQ-9), a nine-item self-reported measure that has been widely used among post-partum women in primary care settings.[56] The scale contains 9 questions about the frequency of symptoms of depression over the past 2 weeks, which are summed to produce a global score (range: 0-27), with higher scores indicating greater depressive symptoms. Scores of 10 or higher on PHQ-9 were considered to indicate having elevated depressive symptoms.[56] We performed a sensitivity analysis to examine whether short sleep duration mediated the association between elevated depressive symptoms and diet quality. We performed the first two steps of a mediation analysis using the Baron & Kenny's approach.[57] We first examined whether elevated depressive symptoms was significantly associated with diet quality, as the first requirement. Then we examined whether elevated depressive symptoms was significantly associated with short sleep duration, as the second requirement. All analyses were conducted using SAS (Version 9.3, SAS Institute Inc., Cary, NC).

Results

Study sample inclusion and exclusion

NHANES 2005-2012 included 1,187 non-pregnant women aged 20 to 44 years old who delivered their youngest child within the past 5 years. We excluded women missing information on sleep duration (n=4), and those who did not complete the first (n=29) or the second dietary recall (n=171), resulting in an analytic sample of 1,012 women. These women represent 12.9 million women with young children nationally.

Sample characteristics

Women were on average 30.7 years old (SE: 0.3). One third of women had given birth within the past year, 22.1% 1-2 years ago, 16.2% 2-3 years ago, 16.8% 3-4 years ago, and 13.2% 4-5 years ago. Women reported an average of 6.9 (SE: 0.05) hours of sleep on weekdays/workdays (median: 7.0 hours, range: 1-12 hours). Short sleep duration was reported by 35.3% of women (with 13.7% women reporting less than 6 hours of sleep), adequate sleep by 56.1%, and long sleep by 8.6% (Table 2.1). Compared to women with adequate sleep duration, women with short sleep were more likely to be obese (41.5% vs. 30.5%), within 1 year of childbirth (40.3% vs. 28.8%), having greater depressive symptoms (4.3 (SE: 0.4) vs. 3.1 (SE: 0.3), and less likely to be non-Hispanic White (54.0% vs. 65.2%), and have an education above college (17.0% vs. 33.8%). Similar differences were observed between women with long and adequate sleep duration (Table 2.1).

Sleep duration and diet quality

The average diet quality score was 47.3 (SE: 0.8) among all women. Total diet quality was 45.4 (SE: 1.2) among women with short sleep duration, 48.8 (SE: 0.8) among women with adequate sleep duration, and 44.6 (SE: 2.5) among women with long sleep duration (Table 2.2). Twelve women (1.4%) had an overall HEI-2010 score over 80, indicating that they followed the dietary guidelines; 10 women reported adequate and 2 reported short sleep duration. Compared to women with adequate sleep duration, women with short sleep duration had lower diet quality in the crude model (Table 2.2). After further adjusting for age, race/ethnicity, and education level, short sleep duration was not associated with diet quality (β =-1.9; 95%CI: -4.7 to 0.9) (Table 2.2). Women with short sleep duration did not differ from women with adequate sleep duration in the consumption of 12 components of diet quality score either (Table 2.2). Overall diet quality did not differ between women with long and adequate sleep duration (β = -2.7; 95% CI: -6.8 to 1.4) (Table 2.2). In the exploratory analyses examining components of diet quality, women with long sleep duration had lower consumption of total fruit (β = -0.6; 95%CI: -1.2 to -0.01), whole fruit (β = -0.7; 95%CI: -1.4 to -0.03), and total protein foods (β = -0.6; 95%CI: -1.2 to -0.01), compared to women with adequate sleep duration (Table 2.2).

Sensitivity analyses

We performed a sensitivity analysis to examine the association between sleep duration and diet quality using Healthy People 2020's definition of short sleep duration for women aged 20-21 years. Seven women aged 20 to 21 years had 7 hours of sleep at night and were categorized as having short sleep duration using Healthy People 2020's definition. The association between sleep duration and diet quality were similar to the original analyses (data not shown). We performed another sensitivity analysis to examine whether sleep duration mediated the association between elevated depressive symptoms and diet quality. After adjusting for age, race/ethnicity, and education level, women with elevated depressive symptoms had poorer diet quality (β =-3.7, 95%CI: -6.8 to -0.5). This met the first mediation requirement of a significant association between elevated depressive symptoms and diet quality.[57] However, it did not meet the second mediation requirement of a significant relation of elevated depressive symptoms to the hypothesized mediator, short sleep duration (OR=1.2, 95%CI: 0.6 to 2.1). Thus, elevated depressive symptoms was not associated with short sleep duration and the pathway between elevated depressive symptoms and poorer diet quality did not go through short sleep duration.

Discussion

This study found that within 5 years of childbirth, U.S. women have, on average, poor diet quality and the majority fails to follow current recommendations for having a good quality diet. Neither short nor long sleep duration was associated with diet quality among U.S. women with young children.

Our finding that neither short or long sleep duration was associated with diet quality was inconsistent with the results of prior studies, which have reported a U-shaped association between sleep duration with diet quality and eating behaviors in the general adult population.[32,34,58] There are several possibilities for this null finding. First, a recent study found a U-shaped association between sleep duration with diet quality among postmenopausal women, in which dietary data was collected via Food Frequency Questionnaires (FFQs).[34] Participants were asked to report the consumption frequencies and portion sizes in the past three months. Although FFQs may provide a better estimation of individuals' long term dietary intake than dietary recalls,[59] exclusion of foods popular to ethnic minority groups that are significant contributors of nutrients will bias the results.[60] Second, measurement error may exist in the measure of dietary intake through 24-hour dietary recalls. Although the 24-hour dietary recall has been used as a reference instrument of dietary intake, studies suggest it suffers from intake-related bias and person-specific bias.[61] Intake-related bias may be due to social desirability that persons with a low intake of supposedly healthy food may be tempted to over report their intake and those with a high intake of supposedly unhealthy food to under report.[61] Person-specific bias is the difference between an individual's reported intake averaged over many repeated measures and their true average intake. It varies from person to person and may relate to personalities.[61] The intake-related bias and person-specific bias introduced by dietary recalls may not be differential between women with short or long versus women with adequate sleep duration, which may bias the study results towards to null. Third, the null finding may be due to measurement error of sleep duration. Sleep duration was self-reported as the usual number of hours of sleep at night on weekdays or workdays. It is possible that women's weekend sleep duration may differ from their weekday or workday sleep duration. Not taking women's weekend sleep duration into account may introduce nondifferential measurement error which may bias the results towards the null. Women may count time in bed as actual time they spent in sleeping, which may also introduce nondifferential measurement error. Additionally, in NHANES, sleep duration was recorded as integer number of hours per night. Women who reported 6.7 hours of sleep would have 7 hours of sleep after rounding. Although they would be grouped as having short sleep duration using the definition from previous literature, they were categorized as having adequate sleep duration in NHANES. While there is no reason to believe that this misclassification differs by diet quality, it may bias our study findings towards the null. Fourth, this null finding may be subject to residual confounding. Women with short sleep duration are more likely to be stressed,[62] and stressed women are more likely to have less healthful diets and lifestyles;[28] unfortunately, NHANES did not collect information about psychosocial stress. Additionally, we found a significant association between short sleep duration and poor diet quality in the unadjusted model, but the association was not significant adjusting for age and education level, suggesting that these characteristics may have explained the observed crude association between short sleep duration and diet quality.

Both short and long sleep duration are common among adults diagnosed with major depressive disorder,[52] and in fact, are symptoms of depression.[56] In a sensitivity analysis we found no evidence that elevated depressive symptoms was associated with sleep duration or sleep duration mediated the association between elevated depressive symptoms and diet quality. It suggested that the pathway between elevated depressive symptoms and poorer diet quality did not go through short sleep duration. It may be that within 5 years of childbirth, women’s sleep duration is impacted by their children,[47] rather than by chronic diseases or mental health conditions as may be the case in other populations. Future studies should explore other psychosocial and behavioral factors which may mediate the association between elevated depressive symptoms and diet quality among women with young children, including poor sleep quality.

Overall, we found that U.S. women within 5 years of childbirth had poor diet quality, with an average total score below 50% of the maximum score. Most strikingly fewer than 2% of women had a good quality diet. This finding was consistent with our previous research which found that U.S. women's diet quality was on average poor up to 10 years following childbirth.[63] In particular, women had suboptimal consumption of greens and beans, seafood and plant protein, and whole grains, with the average score below 40% of the maximum. Beans and peas are great sources of protein, fiber, and many vitamins and minerals. Consuming more beans could improve the overall diet quality.[64] A recent randomized controlled trial reported that increasing fiber intake may lead to other healthy dietary changes and facilitate weight loss.[65] Greater whole grain consumption is also associated with a lower risk of adverse chronic conditions.[1] Thus, promoting the consumption of greens and beans and whole grains may improve overall diet quality among women with young children, which may be a pathway to improve the diet quality and health of the entire family.

This study has additional strengths and limitations. Using data from a large nationally representative survey enabled us to generalize results to non-institutionalized U.S. women with young children aged 20-44 years. The HEI-2010 is a valid and reliable measure of diet quality,[14] which allows analysis of overall and component diet quality. In NHANES, only two recalls were available, fewer than three recalls considered as the gold standard for dietary assessment.[66] As mentioned above, it is difficult to estimate individual's long-term dietary intake with data from two 24-hour dietary recalls. Although nondifferential measurement error exists in the measurement of sleep duration, it is moderately correlated with sleep duration measured with actigraphy,[67] and self-reported sleep duration has been significantly associated with measures of health.[44,45] Lastly, our study was cross-sectional and correlational, precluding causal inference about sleep duration's impact on diet quality.

In conclusion, U.S. women within 5 years of childbirth have, on average, poor diet quality. Diet quality did not differ between women with short and adequate sleep duration or between women with long and adequate sleep duration. Considering the high prevalence of short sleep duration among women with young children, research is needed to understand what factors influence sleep duration among women with young children and how to promote adequate sleep duration among women in this population. Given the important role of diet quality in the prevention of several chronic diseases, and the association between women's and their children's diet quality[27], our findings also suggest the potential utility of examining other behavioral or psychosocial factors which may impact maternal diet quality.

Table 2.1. Characteristics in relation to weekday/workday sleep duration, among US women within 5 years of childbirth, NHANES 2005-2012, Mean ± SE or weighted % (95% CI)

	Short sleep duration (<7 hours)	Adequate sleep duration (7-8 hours)	Long sleep duration (>8 hours)
Sample Size	395	548	69
Weighted Sample Size	4,557,246	7,228,181	1,109,691
Age, Mean (SE)	29.9 ± 0.4	31.2 ± 0.5	30.1 ± 1.0
Age categories			
20-<25	20.7 (15.3 – 26.2)	17.5 (13.1 – 21.9)	23.8 (11.3 – 36.3)
25-<30	27.8 (21.9 – 33.7)	21.0 (15.8 – 26.1)	26.7 (13.7 – 39.7)
30-<35	26.7 (20.2 – 33.1)	28.9 (23.4 – 34.4)	22.0 (9.7 – 34.4)
35-<40	19.1 (12.7 – 25.6)	23.9 (17.2 – 30.5)	15.8 (2.6 – 29.0)
40-44	5.7 (3.6 – 7.8)	8.7 (5.8 – 11.7)	11.7 (3.7 – 19.7)
Years since most recent live birth			
Within one year	40.3 (33.7 – 47.0)	28.8 (23.5 – 34.2)	28.6 (13.1 – 44.1)
Within 1-2 years	19.2 (12.9 – 25.4)	23.9 (19.0 – 28.9)	21.8 (8.1 – 35.4)
Within 2-3 years	14.3 (8.8 – 19.8)	17.4 (13.0 – 21.7)	16.2 (4.8 – 27.6)
Within 3-4 years	16.0 (9.5 – 22.4)	17.2 (13.0 – 21.4)	17.5 (6.4 – 28.7)
Within 4-5 years	10.2 (6.4 – 14.0)	12.6 (8.0 – 17.2)	16.0 (2.2 – 29.7)
Race/ethnicity			
Non-Hispanic White	54.0 (45.5 – 62.4)	65.2 (58.9 – 71.5)	64.5 (48.5 – 80.6)
Non-Hispanic Black or African American	20.6 (15.4 – 25.7)	8.4 (5.3 – 11.4)	10.6 (4.0 – 17.2)
Hispanic/Latino/Spanish origin	22.6 (17.4 – 27.8)	19.7 (14.6 – 24.9)	19.4 (7.4 – 31.5)
Other race(s), including multi-racial	2.9 (0.8 – 4.9)	6.7 (4.0 – 9.4)	5.4 (0 – 12.6)
Education level			
Less than high school	20.2 (15.2 – 25.3)	16.5 (12.3 – 20.8)	26.8 (12.3 – 41.3)
High school graduate/GED	24.3 (17.8 – 30.8)	21.3 (16.3 – 26.3)	23.5 (9.4 – 37.6)
Some college /Associate’s degree	38.5 (31.5 – 45.4)	28.4 (22.9 – 33.9)	28.7 (15.8 – 41.6)

College graduate or above	17.0 (11.1 – 22.9)	33.8 (27.1 – 40.4)	21.0 (8.1 – 33.9)
Poverty income ratio (PIR)			
<100% FPL	27.3 (21.7- 33.0)	19.8 (15.8 – 23.9)	43.9 (28.0 – 59.8)
100-300% FPL	45.5 (37.9 – 53.1)	39.2 (33.4 – 45.1)	22.8 (7.0 – 38.6)
>300% FPL	27.2 (18.7 – 35.6)	40.9 (34.6 – 47.2)	33.3 (16.0 – 50.6)
Marital status			
Married or living with someone	77.1 (72.2 – 82.)	81.5 (76.9 – 86.0)	82.7 (71.3 – 94.2)
Separated or widowed or divorced	9.1 (5.7 – 12.5)	5.5 (3.7 – 7.2)	1.5 (0 – 3.6)
Never married	13.8 (10.6 – 17.0)	13.1 (8.7 – 17.5)	15.9 (4.7 – 27.0)
Smoking status			
Never smoker	56.9 (48.7 – 65.1)	66.1 (61.1 – 71.1)	49.2 (33.1 – 65.3)
Past smoker	28.5 (21.1 – 35.9)	19.2 (15.1 – 23.3)	39.8 (22.9 – 56.8)
Current smoker	14.6 (8.5 – 20.8)	14.7 (10.1 – 19.4)	11.0 (0.4 – 21.5)
Weight status			
Underweight	2.4 (0.5 – 4.3)	2.1 (0.5 – 3.7)	5.3 (0 – 11.5)
Normal weight	27.7 (20.9 – 34.4)	39.7 (34.4 – 45.1)	34.3 (19.2 – 49.5)
Overweight	28.4 (22.0 – 34.8)	27.6 (21.7 – 33.4)	27.9 (14.4 – 41.5)
Obese	41.5 (33.8 – 49.2)	30.5 (24.9 – 36.1)	32.4 (15.4 – 49.5)
Household food security			
Full	62.0 (54.6 – 69.3)	73.6 (68.5 – 78.8)	69.5 (55.6 – 83.3)
Marginal	13.9 (9.8 – 18.0)	11.2 (8.2 – 14.2)	7.7 (0.5 – 14.9)
Low or very low	24.1 (18.2 – 30.1)	15.1 (11.0 – 19.2)	22.9 (8.7 – 37.0)
Household size	4.3 ± 0.1	4.2 ± 0.1	4.1 ± 0.2
Household size			
Two	4.4 (2.2 – 6.6)	4.5 (2.1 – 6.9)	8.3 (0 – 17.8)
Three	29.9 (20.6 – 39.1)	29.0 (24.1 – 34.0)	25.1 (12.0 – 38.3)
Four	27.0 (20.9 – 33.1)	31.9 (26.3 – 37.5)	28.6 (14.9 – 42.2)
Five or more	38.7 (31.1 – 46.3)	34.6 (29.2 – 40.0)	38.0 (23.0 – 53.0)
Depressive symptoms	4.3 ± 0.4	3.1 ± 0.3	3.5 ± 0.8
Elevated depressive symptoms	14.3 (8.3 – 20.4)	10.5 (8.3 – 20.4)	13.9 (1.2 – 26.6)

Meeting physical activity guideline	29.4 (22.5 – 36.3)	32.3 (26.0 – 38.6)	30.9 (14.9 – 47.0)
Ever diagnosis of diabetes	1.5 (0.3 – 2.8)	2.8 (0.6 – 5.1)	0.2 (0 – 0.5)
Ever diagnosis of GDM	7.2 (3.8 – 10.6)	12.2 (8.2 – 16.2)	--
Ever diagnosis of hypertension	12.5 (7.6 – 17.4)	7.9 (4.8 – 11.0)	14.6 (1.4 – 27.8)

* Missing data for variables: poverty income ratio (n=68), marital status (n=1), weight status (n=3), household food security (n=5), household size (n=1), depressive symptoms (n=2), physical activity (n=199, all due to no data collection in NHANES 2005-06), ever diagnosis of hypertension, and ever diagnosis of gestational diabetes mellitus (n=209, n=199 due to no data collection in NHANES 2005-06)

Table 2.2. Diet quality (HEI-2010) in relation to weekday/workday sleep duration, among U.S. women within 5 years post-childbirth, NHANES 2005-2012*

HEI-2010 score (possible maximum score)	Adequate sleep duration (7-8 hours)*	Short sleep duration (<7 hours)			Long sleep duration (>8 hours)		
	M±SE	M±SE	Crude beta (95% CI)	Adjusted** beta (95% CI)	M±SE	Crude beta (95% CI)	Adjusted** beta (95% CI)
Total diet quality (100)	48.8±0.8	45.4±1.2	**-3.4 (-6.0 to -0.7)**	-1.9 (-4.7 to 0.9)	44.6±2.5	-4.2 (-9.0 to 0.6)	-2.7 (-6.8 to 1.4)
Total fruit (5)	2.6±0.1	2.3±0.2	-0.2 (-0.6 to 0.2)	-0.2 (-0.5 to 0.2)	1.9±0.3	**-0.8 (-1.3 to -0.1)**	**-0.6 (-1.2 to -0.01)**
Whole fruit (5)	2.4±0.1	2.2±0.2	-0.2 (-0.6 to 0.2)	0.01 (-0.4 to 0.4)	1.5±0.3	**-0.9 (-1.7 to -0.1)**	**-0.7 (-1.4 to -0.03)**
Total vegetable (5)	3.5±0.1	3.2±0.1	**-0.3 (-0.5 to -0.04)**	-0.2 (-0.4 to 0.1)	3.1±0.3	-0.4 (-1.0 to 0.2)	-0.3 (-0.9 to 0.3)
Greens and beans (5)	1.6±0.1	1.4±0.1	-0.3 (-0.6 to 0.1)	-0.1 (-0.5 to 0.2)	1.9±0.4	0.3 (-0.4 to 1.0)	0.4 (-0.3 to 1.1)
Total protein foods (5)	4.3±0.1	4.2±0.1	-0.1 (-0.4 to 0.1)	-0.2 (-0.4 to 0.1)	3.7±0.3	-0.6 (-1.2 to 0.004)	**-0.6 (-1.2 to -0.01)**
Seafood and plant protein (10)	2.3±0.1	1.8±0.1	**-0.5 (-0.8 to -0.2)**	-0.3 (-0.6 to 0.1)	2.2±0.3	-0.1 (-0.7 to 0.6)	0.1 (-0.4 to 0.7)
Whole grain (10)	2.3±0.2	1.7±0.2	**-0.6 (-1.2 to -0.1)**	-0.4 (-0.9 to 0.2)	1.5±0.4	**-0.8 (-1.6 to -0.1)**	-0.6 (-1.4 to 0.2)

Dairy (10)	6.2±0.2	5.4±0.3	-0.8 (-1.5 to -0.1)	-0.5 (-1.2 to 0.1)	5.5±0.6	-0.7 (-2.0 to 0.6)	-0.5 (-1.8 to 0.8)
Fatty acids (10)	4.4±0.2	4.5±0.2	0.1 (-0.4 to 0.7)	0.1 (-0.5 to 0.7)	4.4±0.5	-0.04 (-1.1 to 1.0)	0.02 (-1.0 to 1.0)
Sodium (10)	4.1±0.2	4.2±0.2	0.1 (-0.5 to 0.8)	-0.04 (-0.7 to 0.6)	4.8±0.7	0.7 (-0.7 to 2.2)	0.6 (-0.8 to 2.0)
Refined grain (10)	4.9±0.2	5.1±0.3	0.3 (-0.4 to 1.0)	0.2 (-0.6 to 0.9)	6.0±0.6	1.1 (-0.2 to 2.5)	1.1 (-0.3 to 2.5)
Empty calories from added sugar, solid fat, and alcohol (20)	10.3±0.5	9.3±0.6	-1.0 (-2.3 to 0.3)	-0.3 (-1.8 to 1.1)	8.2±1.2	-2.1 (-4.4 to 0.2)	-1.6 (-3.6 to 0.5)

* Adequate sleep duration = reference group

** Adjusted for age, race/ethnicity, and education level

CHAPTER III

SLEEP QUALITY AND DIET QUALITY AMONG WOMEN WITH YOUNG CHILDREN IN THE UNITED STATES

Abstract

Objective: Many women with young children have suboptimal diet quality, which may have negative health consequences for themselves and their children. While short sleep duration is associated with poor diet quality, little is known about the impact of poor sleep quality on diet quality. We examined the association between sleep quality and diet quality among U.S. women with young children.

Methods: Eligible participants were non-pregnant women aged 20-44 years within 5 years of childbirth who completed two 24-hour dietary recalls (N=481) in the National Health and Nutrition Examination Survey (NHANES) 2005-2008. Poor sleep quality was indicated by report of ≥1 of 6 sleep problems ≥5 times in the past month. The Healthy Eating Index (HEI-2010, range: 0-100) estimated overall and components of diet quality (e.g., consumption of fruit and vegetables, protein, sodium, and empty calories). Multivariable adjusted linear regression models estimated the association between sleep quality and diet quality, adjusting for age and smoking status.

Results: Fifty-five percent of women reported poor sleep quality. The average HEI score was 47.7. Poor sleep quality was not associated with diet quality (β=-4.4, 95%CI: -8.5 to -0.3) Specifically 4 of the six sleep problems – having trouble getting asleep, waking up at night, feeling sleepy, and not getting enough sleep – were associated with poorer diet quality.

Conclusions: Among US women with young children, overall poor sleep quality and specific sleep problems were associated with poorer diet quality. Research is needed to explore whether improvement in sleep quality may improve diet quality among women

with young children, which has the potential to improve both maternal and children's health.

Introduction

Diet quality encompasses both the components and variety of the diet. As measured by the Healthy Eating Index (HEI)-2010, diet quality indicates how closely people's diet align with the Dietary Guidelines for Americans 2010.[14] The HEI-2010 includes 12 components: total fruit (including fruit juice), whole fruit, total vegetables, greens and beans, whole grains, diary, total protein foods, seafood and plant proteins, fatty acids, refined grains, sodium, and empty calories; higher scores indicate higher diet quality.[14] A high quality diet is associated with reduced risk of all-cause mortality[12] and several chronic diseases, including obesity, type 2 diabetes, and cardiovascular disease.[9–11] Diet quality is particularly important for women with young children, given that it may impact their children's diet quality.[27,53] However, in one study, only 9% of overweight and obese women with preschool-aged children consumed a good diet quality.[27] Research is needed to understand factors that may contribute to poor diet quality in women with young children.

Poor sleep quality, characterized by nighttime awakening and sleep fragmentation, is common among women with infants and young children.[35,36,46–48] Poor sleep quality is associated with decreases in plasma levels of leptin and increases in serum levels of ghrelin,[34,40] which may impact appetite regulation,[41] and stimulate the consumption of energy-dense foods [42,43] and consequently contribute to poorer diet quality [34,37] and higher energy intake.[34,44] Sleep deprivation has been linked to meal skipping, higher energy intake from snacks, greater consumption of sugar, and a higher percentage of energy intake from beverages among adults generally.[45] However, no studies to date have examined the association between sleep quality and diet quality among women with young children. The purpose of this study was to examine the association between sleep quality and diet quality among U.S. women with young children. We hypothesized that poor sleep quality and each aspect of poor sleep quality would be associated with poorer diet quality. We also explored the associations between sleep quality and each component of diet quality.

Studies have observed a bidirectional association between sleep quality and depression,[68] with poor sleep being a common symptom of depression.[69] Depressive symptoms are associated with unhealthful diet among post-partum women.[70] Thus, elevated depressive symptoms may be a root cause of poor quality sleep among women with young children, and simply adjusting for it in regression models may mask the observed association between sleep quality and diet quality. Thus, we performed a sensitivity analysis to examine whether poor sleep quality mediated the association between elevated depressive symptoms and diet quality.

Methods

Study design and participants

We used data from the National Health and Nutrition Examination Survey (NHANES), nationally representative cross-sectional surveys of non-institutionalized Americans.[71] NHANES employs a complex multi-stage probability cluster design.[54] Participants completed in-person interviews at their homes and at a Mobile Examination Center (MEC) and subsequently a follow-up interview via phone. Full details of the sampling methodology and data collection procedures used in NHANES are available.[54] We combined data from cycles 2005-06 and 2007-08 because information on sleep quality was only collected during these two cycles. Our analytic sample included women aged 20 to 44 years old who delivered their youngest child within the past 5 years and who completed two dietary interviews. The University of Massachusetts Medical School Institutional Review Board deemed this study exempt from human subject research oversight.

Sleep quality

Participants answered six questions about sleep quality in the past month as part of the routinely administered sleep disorders questionnaire: "In the past month, how often did you have trouble falling sleep?", "how often did you wake up during the night and have trouble getting back to sleep?", "how often did you wake up too early in the morning, and were unable to get back to sleep?", "how often did you feel unrested during the day, no matter how many hours of sleep?", "how often did you feel excessively or overly sleepy during the day?", and "how often did you not get enough sleep?". Response options were never, rarely (1 time a month), sometimes (2-4 times a month), often (5-15 times a month), almost always (16-30 times a month), refused, and don't know. Participants were classified as having poor sleep quality if they answered "often" or "almost always" (together defined as 5-30 times last month) to any one of the six questions above as had been done in previous research.[72] Otherwise, they were classified as having adequate sleep quality. We also examined each of the six components of sleep quality separately using the same criteria for “poor sleep quality”.

Diet quality

Dietary data were collected through the completion of two 24-hour dietary recalls. Women completed the first recall together with in-person interviews at MEC, and the second on the phone 3 to 10 days later.[71] During both interviews, participants reported types and amounts of foods and beverages they ate from midnight to midnight on the day before the interview. We used the HEI-2010 to quantify diet quality.[9] HEI-2010 is a valid and reliable diet quality index that measures conformance with the Dietary Guidelines for Americans.[14] Nine components of the HEI-2010 are adequacy components where a high score represents greater consumption (total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant proteins, and the ratio of poly- and monounsaturated fatty acids to saturated fatty acids). The other three are moderation components, where a higher score represents lower consumption (refined grains, sodium, and empty calories from solid fats, alcohol, and added sugars). Components were weighted differently according to their relative importance to the overall score and contributed a maximum of 5 to 20 points to the total possible 100 points score. Intakes between the minimum and maximum standards were scored proportionately. We used the documented SAS code, MyPyramid Equivalents Database (MPED), CNPP MyPyramid Equivalents Databases and CNPP Addendum to the MPED (version 2.0B) to calculate the dietary intake of each HEI component for each dietary recall. We then calculated the average dietary intake from two dietary recalls and used this average intake to calculate each HEI-2010 component score and the total score. The documented SAS code is available at http://www.cnpp.usda.gov/healthy-eating-index-support-files-07-08. Higher HEI-2010 scores indicate better diet quality. Women with HEI-2010 total score over 80 were considered having a good quality diet, as in prior studies.[14]

Covariates

Participants self-reported age, race/ethnicity, education level, marital status, annual household income, smoking status, physical activity level, sleep duration, and history of several chronic diseases. These variables were evaluated for potential confounding due to their associations with sleep quality[52,73–77] and/or diet quality.[74,78–81] Household poverty income ratio (PIR) was calculated as the ratio of annual household income to federal poverty level (FPL) for a household of that size and was categorized as <100% FPL, 100-300% FPL, and >300% FPL. Household food security was assessed using the US Food Security Survey Module questions and was categorized by NHANES as full, marginal, low and very low food security.[82] Physical activity level was categorized as following current physical activity guidelines if the person engaged in 150 minutes or more of moderate-intensity activity per week.[83] Participants self-reported the integer number of hours of sleep they usually get at night on weekdays and workdays and sleep duration was categorized as short (<7 hours per night), adequate (7-8 hours per night), and long sleep duration (>8 hours per night).[44,45] Participants also reported diagnoses of several health diseases including hypertension, diabetes, and gestational diabetes mellitus. Body mass index (kg/m^2) was calculated from measured height and weight and categorized as underweight (BMI <18.5kg/m^2), normal weight (18.5 ≤BMI<25kg/m^2), overweight (25≤ BMI <30kg/m^2), and obese (BMI≥30kg/m^2).[84]

Statistical analyses

All statistical analyses accounted for sample weights and the complex survey design to derive national estimates of women with young children. As recommended in the NHANES analytic guidelines,[85] we created a combined 4-year weight by assigning one half of the 2-year weight for each survey cycle (2005-06 and 2007-08).

We used linear regression models to estimate the association between overall sleep quality and diet quality, with women with adequate sleep quality serving as the reference group. For each potential confounder, we used a complete case sample excluding participants missing information on that confounder and examined whether it was associated with overall diet quality with a p value of < 0.25. Potential confounders were included and retained in the adjusted model if the regression coefficient changed appreciably (i.e., by about 10%). We redefined our final analytic sample only including eligible women without missing information on covariates that were included in the adjusted model. We also constructed multivariable-adjusted linear regression models to estimate the association between sleep quality and each component of diet quality, adjusting for the covariates retained in the adjusted model for overall diet quality in order to facilitate the interpretation. We explored the association between each component of sleep quality and total diet quality scores using multivariable-adjusted linear regression models, adjusting for the same set of covariates included in the adjusted models for overall sleep quality. In sensitivity analyses, we additionally adjusted for sleep duration in order to estimate the association between sleep quality and diet quality independent of sleep duration.

We also perform a sensitivity analysis to examine whether poor sleep quality may mediate the association between elevated depressive symptoms and poor diet quality. Depressive symptoms were assessed using the Patient Health Questionnaire (PHQ-9),[86] a nine-item questionnaire of the frequency of depressive symptoms over the past 2 weeks. This measure is commonly used to screen adults for depressive symptoms in the primary care setting.[87] PHQ-9 scores range from 0 to 27, with higher scores indicating greater depressive symptoms. Participants who scored 10 or higher were considered to have clinically meaningful depressive symptoms at a level indicating elevated depressive symptoms.[86] We performed the mediation analysis using the Baron & Kenny's approach.[57] We first examined whether the determinant (elevated depressive symptoms) was significantly associated with the outcome (diet quality), as the first requirement. Second, we examined whether elevated depressive symptoms was significantly associated with the mediator (poor sleep quality), as the second requirement. Third, we examined whether there was a significant association between poor sleep quality and diet quality after adjusting for elevated depressive symptoms, as the third requirement. Lastly, we compared the regression coefficient for elevated depressive symptoms for the first and the third step to determine whether there was full or partial mediation of poor sleep quality for the association between elevated depressive symptoms and poorer diet quality. All analyses were conducted using SAS (Version 9.3, SAS Institute Inc., Cary, NC, USA).

Results

Study sample inclusion and exclusion

NHANES 2005-2008 included 559 non-pregnant women aged 20 to 44 years old who delivered their youngest child within the past 5 years. We excluded women who had missing information for at least one sleep quality question (n=2) and who did not complete the first (n=15) or the second dietary recall (n=76), resulting in an analytic sample of 481 women. These women represent 13.8 million women with young children nationally.

Overall sample characteristics

Women were 30.6 (SE: 0.5) years old on average, 64.4% were non-Hispanic White, 55.5% had a college education or higher, and 78.5% were married or living with a partner. About one in seven women were current smokers, and 24.9% were former smokers. Twenty-night percent were overweight, 35.4% obese, and 2.9% underweight; 33.1% were normal weight. The average depressive symptoms score was 3.4 (SE: 0.3); 12.2% had elevated depressive symptoms. One third were within one year of childbirth, 19.2% were between 1-2 years of childbirth, and 49.2% had last given birth 2-5 years ago.

Sample characteristics by sleep quality

Fifty-five percent of women with young children reported experiencing at least one of the six sleep problems at least 5 times per month, indicative of overall poor sleep quality. Women with poor sleep quality had higher depressive symptoms (4.5 (SE: 0.3) vs. 2.1 (SE: 0.3)) and were more likely to have elevated depressive symptoms (18.7% vs. 4.3%; Table 3.1) compared to women with adequate sleep quality. Sleep duration also differed by sleep quality; 44.9% of women with poor quality reported short sleep duration and 6.7% long sleep duration compared to 25.0% and 11.9%, respectively, of women with adequate sleep quality (Table 3.1). The distribution of smoking status also differed by sleep quality. Other characteristics did not differ by sleep quality (Table 3.1).

Overall sleep quality and diet quality

Women's average diet quality score was 47.7 (SE: 1.1), and only 0.6% had a diet quality score over 80/100, indicating good diet quality. Among women with poor sleep quality, the average diet quality score was 45.0 (SE: 1.5), and among women with adequate sleep quality it was 51.0 (SE: 1.2). Compared to women with adequate sleep quality, women with poor sleep quality had poorer diet quality (β=-4.4; 95%CI: -8.5 to -0.3) adjusting for age and smoking status (Table 3.2). In the secondary analysis of components of diet quality, women with poor sleep quality had lower consumption of total fruit (β =-0.2; 95% CI: -0.3 to -0.1; Table 3.2). No other components of diet quality differed by overall sleep quality (Tale 3.2).

Sleep quality problems and diet quality

The prevalence of individual sleep quality problems ranged from 12.6% (waking up too early in the morning and having trouble getting back to sleep) to 36.0% (feeling unrested during the day no matter how many hours of sleep; Table 3.3). After adjusting for age and smoking status, women who had trouble getting to sleep (β=-4.5; 95%CI: -8.5 to -0.4), who woke up during the night and had trouble returning back to sleep (β=-5.2; 95%CI: -9.7 to -0.7), who felt excessively or overly sleepy during the day (β=-5.1; 95%CI: -9.4 to -0.9), and who reported that they didn't have enough sleep (β=-5.2; 95%CI: -9.3 to -1.1) had a lower diet quality score compared to women who didn't report these problems (Table 3.3). The other two sleep problems – waking up early the morning and unable to get back to sleep, and feeling unrested during the day – were not associated with diet quality (Table 3.3).

Sensitivity analyses of sleep duration

We performed sensitivity analyses further adjusting for self-reported sleep duration in the multivariable model for the association between overall sleep quality and diet quality, between overall sleep quality and components of diet quality, and between specific sleep problems and overall diet quality. Including sleep duration in the model did not change the results, suggesting that the observed associations between sleep quality and diet quality were independent of sleep duration (data not shown).

Sensitivity analyses of the role of elevated depressive symptoms

We explored whether poor sleep quality might mediate the association between elevated depressive symptoms and poor diet quality by performing the Baron & Kenny mediation analysis.[57] After adjusting for age and smoking status, women with elevated depressive symptoms had poorer diet quality (β =-2.7, 95%CI: -4.2 to 1.3). This met the first mediation requirement of a significant association between the determinant (elevated depressive symptoms) and the outcome (diet quality). It also met the second requirement of a significant association between elevated depressive symptoms and the mediator, poor sleep quality: women with elevated depressive symptoms had 4.4 times the odds of having poor sleep quality compared to women without elevated depressive symptoms (OR=4.4, 95%CI: 1.7 to 11.1). After including elevated depressive symptoms in the adjusted model, poor sleep quality was still significantly associated with poorer diet quality (β =-1.0, 95%CI: -1.8 to -0.3), which met the third requirement. Fourth, we found the attenuation of the regression coefficient for elevated depressive symptoms in the model with poor sleep quality versus without. We confirmed that poor sleep quality mediated the association between elevated depressive symptoms and poor diet quality.

Discussion

In this study, overall sleep quality was associated with poorer diet quality among US women with young children. Four specific aspects of sleep quality – having trouble getting to sleep, waking up during the night and having trouble returning to sleep, feeling sleepy during the day, and not getting enough sleep – were also associated with poorer diet quality. We also found that poor sleep quality mediated the association between elevated depressive symptoms and poor diet quality among U.S. women with young children.

The results of this study confirmed our hypothesis that poor sleep quality would be associated with poor diet quality in U.S. women with young children. Emerging evidence has linked disrupted sleep to increased food intake[88] and poorer diet quality,[89] through homeostatic and non-homeostatic pathways. Poor sleep quality is associated with decreases in leptin levels and increases in ghrelin levels,[34,40] which may impact appetite regulation,[41] and stimulate the consumption of energy-dense foods [42,43] and consequently poorer diet quality [34,37] and higher energy intake.[34,44] Poor sleep quality may also be associated with impairments in executive functioning through the impairments in the pre-frontal cortex.[89] In adults, weaker executive control is related to a greater consumption of snacks and high-fat food and lower consumption of fruit and vegetables,[90] which may contribute to poorer diet quality. Considering the observed association between poor sleep quality and poor diet quality, research is needed to explore whether improvements in sleep quality may contribute to improvements in diet quality among women with young children, which has the potential to improve both maternal and children's health.

Additionally, the NHANES sleep quality assessment measures sleep quality problems in the general adult population, which may not fully capture the fragmentation feature of poor sleep quality among women with young children. A recent study found that child night wakening was most highly associated with poor sleep quality among women with young children.[91] Women with young children may get woken up at night frequently but may not have trouble getting back to sleep, and thus answering never or rarely to the question of waking up during the night and having trouble getting back to sleep doesn’t necessarily mean that they did not wake up during the night. Research is needed to explore whether additional or alternative assessment of sleep quality may more fully capture aspects of sleep quality and sleep disruptions unique to and common among women with young children.

Our findings that four specific aspects of sleep quality were associated with diet quality were consistent with prior studies,[92,93] and our study expands this previous research by examining the association between overall sleep quality and diet quality in addition to specific sleep quality problems. In a study sample of adults aged over 18 years, waking up during the night and having trouble returning back to sleep was associated with lower food variety and fewer numbers of food consumed per day.[93] Daytime sleepiness was associated with increased calorie intake, and fewer numbers of food consumed per day.[93] Having trouble getting to sleep, waking up during the night and having trouble returning to sleep, and feeling sleepy during the day were also associated with nutrients intake, such as less calcium, less potassium, less vitamin C, and less vitamin D.[93] Having trouble falling asleep and maintaining sleep were also associated with lower protein and lower carbohydrate intake.[92] In the present study, women's subjective perception of how much sleep they get was associated with poorer diet quality. Information on women's subjective perception of sleep duration inadequacy was ascertained by asking women "In the past month, how often did you not get enough sleep?", and sleep duration was self-reported as the number of hours of sleep women usually get at night on weekdays or workdays. Forty-one percent of women with short sleep duration (<7 hours) reported getting enough sleep, and 12% of women with long sleep duration (>8 hours) said they did not get enough sleep. The disconnect between actual and perceived sleep duration may be due to inaccurate estimation of their actual sleep or due to their not feeling rested after what is considered adequate sleep duration, or individual variation in needed sleep duration. It may also be that women with adequate sleep duration that is disrupted feel that they do not have enough sleep. When we adjusted for objective short sleep duration based on women's self-reported typical sleep duration on weekdays/workdays, results were similar; suggesting that in this population, perceiving oneself to not get enough sleep is associated with poorer diet quality independent of actual sleep duration. Future studies are needed to explore women with young children's perceived adequacy of sleep duration, how this relates to objectively measured sleep duration, and possible linkages with diet quality and eating behaviors.

Our sensitivity analyses suggested that poor sleep quality might mediate the association between elevated depressive symptoms and poor diet quality among women with young children, supporting our conceptual model that elevated depressive symptoms may lead to poor sleep quality, and elevated depressive symptoms affected diet quality through the pathway of poor sleep quality. Previous studies estimated the national prevalence of depression among women with young children to be 13%,[94] similar to the 12% observed in the current study. Given the negative consequences of elevated depressive symptoms for women and their children,[95] treating depression is a priority for women who exhibit elevated depressive symptoms. Treatment for depression should include sleep assessment, as improving sleep in depressed patients has been found to improve mental health outcomes,[96] and may also lead to better diet quality as our finding suggested. Thus, treating depression among women with young children may not only provide great benefit for their mental health, but may also have a collateral positive impact on their diet quality, to the extent that depressive symptoms affect eating behaviors and thus diet quality.

We found that more than half of U.S. women with young children reported poor sleep quality, consistent with previous research of mothers of infants, toddlers, and preschoolers.[35,48,97] Women with young children may be particularly vulnerable to poor sleep quality and sleep disturbances given the physical, physiological, and psychosocial changes before and after childbirth.[46] Given the links between poor sleep quality and chronic disease risk,[98–100] our study emphasizes the need to address and improve sleep quality among women with young children, which may correspondingly improve maternal diet quality and their children's diet quality to the extent to which sleep quality negatively impacts diet quality in this population.

This study has additional strengths and limitations. NHANES is a nationally representative survey of non-institutionalized Americans, and thus our findings can be generalized to US women aged 20 to 44 years who gave birth within the past 5 years. NHANES assessed detailed demographic, clinical, and dietary information. Dietary information was collected by trained interviewers under monitoring throughout the data collection period. The HEI-2010 is a valid and reliable and widely used measure of diet quality.[14] Although 24 hour dietary recall has been used as a reference instrument of dietary intake, it is vulnerable to intake-related bias and person-specific bias.[61] Due to social desirability, individuals with a low intake of supposed healthy food may be tempted to over report their intake and those with a high intake of supposedly unhealthy food to under report. [61] Nondifferential measurement error from 24-hour dietary recalls may bias the results towards the null. As individuals' dietary intake may variate due to day-to-day fluctuations on dietary exposure, dietary data collected via two 24-hour recalls may not be sufficient to estimate participants' usual dietary intake.[66] Food frequency questionnaires (FFQs) may be good alternatives for estimation of individuals' usual and long-term dietary intake,[61] which may require adjustment of underreporting of energy consumption. Although the sleep quality measure in NHANES has not been validated against objectively measured sleep quality, previous studies have observed significant associations between this measure of sleep quality and several measures of health, including pre-diabetes,[99] inflammation,[101] and hypertension.[72] Another potential limitation is unmeasured confounding. We were unable to adjust for other variables previously found to impact both sleep quality and diet quality, such as current breastfeeding behaviors,[102–104] as these data were not collected in NHANES. To the extent that breastfeeding may be associated with poorer sleep quality[103] and better diet quality,[104] failure to adjust for current breastfeeding behaviors may underestimate the association between poor sleep quality and poor diet quality and bias the result towards the null. Lastly, the cross-sectional study design precludes causal inferences.

Conclusions

Overall sleep quality was associated with poorer diet quality among US women with young children; in addition, four specific sleep problems were also associated with poorer diet quality, including trouble getting asleep, waking up during the night and unable to get back to sleep, feeling sleepy during the day, and not getting enough sleep. Given the average poor diet quality and the relatively high prevalence of poor sleep quality among U.S. women with young children, future studies are needed to explore whether improvement in sleep quality may contribute to better diet quality in this population, which has the potential to improve both maternal and children's health.

Table 3.1. Participant characteristics in relation to sleep quality among US women within 5 years after childbirth, NHANES 2005-2008, Mean ± SE or weighted % (95% CI)

	Adequate sleep quality	Poor sleep quality
Sample N	232	249
Weighted N	6,267,206	7,548,837
Age (years)	31.2 ± 0.8	30.2 ± 0.5
Race/ethnicity		
Non-Hispanic white	57.7 (47.6 – 67.8)	69.9 (61.6 – 78.1)
Non-Hispanic black or African American	13.1 (7.0 – 19.1)	12.0 (6.9 – 17.1)
Hispanic/Latino/Spanish origin	25.2 (18.2 – 32.1)	15.1 (9.9 – 20.3)
Other race(s), including multi-racial	4.1 (0 – 8.2)	3.0 (0.4 – 5.7)
Education level		
Less than high school	23.4 (15.5 – 31.4)	19.5 (11.6 – 27.4)
High school graduate/GED	21.7 (15.0 – 28.4)	24.4 (15.8 – 33.0)
Some college/Associate's degree	29.5 (20.5 – 38.6)	36.0 (28.3 – 43.7)
College graduate or above	25.3 (16.4 – 34.2)	20.1 (10.3 – 29.9)
Poverty income ratio (PIR)		
<1	22.2 (15.1 – 29.3)	23.7 (16.7 – 30.7)
1-3	41.1 (32.7 – 49.6)	39.5 (31.0 – 48.0)
>3	36.6 (25.5 – 47.7)	36.7 (28.1 – 45.3)
Marital Status		
Married or living with someone	79.2 (72.6 – 85.9)	78.0 (69.6 – 86.3)
Separated or widowed or divorced	6.0 (1.4 – 10.6)	8.2 (3.4 – 13.0)
Never married	14.8 (7.8 – 21.7)	13.8 (7.4 – 20.2)
Smoking status		
Never smoker	65.9 (56.6 – 75.2)	54.0 (44.4 – 63.6)
Past smoker	15.9 (9.9 – 22.0)	32.4 (24.5 – 40.3)
Current smoker	18.2 (12.1 – 24.3)	13.6 (4.6 – 22.6)
Weight status		
Underweight	1.2 (0 – 2.7)	4.3 (0.9 – 7.8)
Normal	35.4 (24.6 – 46.2)	31.2 (23.2 – 39.2)
Overweight	25.9 (17.1 – 34.6)	30.9 (20.8 – 41.0)
Obese	37.5 (27.4 – 47.6)	33.6 (23.8 – 43.3)
Household food security		
Full	75.9 (66.7 – 85.1)	71.8 (64.7 – 78.9)
Marginal	9.1 (3.7 – 14.4)	12.5 (7.3 – 17.6)
Low or very low	15.1 (8.1 – 22.0)	15.8 (9.6 – 21.9)
Household size		
Two people	4.4 (0.6 – 8.2)	3.4 (0.1 – 6.7)
Three people	25.9 (18.8 – 33.1)	39.0 (31.6 – 46.4)

Four people	33.4 (26.0 – 40.7)	23.9 (18.1 – 29.8)
Five or more people	36.3 (28.9 – 43.7)	33.6 (25.1 – 42.0)
Years since most recent live birth		
Within 1 year	27.2 (17.8 – 36.6)	35.2 (27.1 – 43.3)
1-2 years	21.9 (14.8 – 29.1)	17.0 (9.9 – 24.0)
2-5 years	50.8 (40.8 – 60.9)	47.8 (37.9 – 57.7)
Sleep duration		
Short (<7 hours)	25.0 (17.7 – 32.3)	44.9 (36.6 – 53.2)
Adequate (7-8 hours)	63.1 (54.6 – 71.6)	48.4 (41.2 – 55.6)
Long (>8 hours)	11.9 (5.0 – 18.8)	6.7 (2.0 – 11.5)
Depressive symptoms	2.1 ± 0.3	4.5 ± 0.3
Elevated depressive symptoms	4.3 (1.3 – 7.3)	18.7 (11.9 – 25.6)
Meeting physical activity guideline	34.5 (23.3 – 45.6)	34.1 (19.3 – 48.8)
Ever diagnosis of diabetes	4.9 (0 – 9.8)	2.0 (0.6 – 3.3)
Ever diagnosis of gestational diabetes mellitus (GDM)	8.6 (2.4 – 14.9)	6.9 (2.8 – 10.9)
Ever diagnosis of hypertension	5.4 (3.2 – 7.7)	5.1 (3.5 – 6.8)

* Missing data: poverty income ratio (n=31), marital status (n=1), weight measures (n=1), household food security (n=3), depressive symptoms (n=1), level of physical activity (n=199, all due to no data collection in NHANES 2005-06), ever diagnosis of gestational diabetes mellitus (n=204, n=199 due to no data collection in NHANES 2005-06).

Table 3.2. Diet quality in relation to sleep quality among women within 5 years after childbirth, NHANES 2005-2008

Diet quality components (Maximum score)	Adequate quality sleep M ± SE	Poor quality sleep M ± SE	Crude model, β (95% CI)*	Adjusted model β (95% CI)**
Total diet quality (100)	51.0 ± 1.2	45.0 ± 1.5	**-6.0 (-9.6 to -2.4)**	**-4.4 (-8.5 to -0.3)**
Total fruit (5)	2.7 ± 0.2	1.9 ± 0.2	**-0.7 (-1.1 to -0.3)**	**-0.2 (-0.3 to -0.1)**
Whole fruit (5)	2.4 ± 0.2	1.7 ± 0.2	**-0.7 (-1.3 to -0.1)**	-0.5 (-1.0 to 0.03)
Total vegetable (5)	3.5 ± 0.1	3.3 ± 0.1	-0.2 (-0.6 to 0.2)	-0.1 (-0.5 to 0.3)
Greens and beans (5)	1.7 ± 0.2	1.4 ± 0.1	-0.3 (-0.8 to 0.2)	-0.2 (-0.6 to 0.3)
Total protein foods (5)	4.4 ± 0.1	4.2 ± 0.1	-0.2 (-0.6 to 0.2)	-0.1 (-0.4 to 0.3)
Seafood and plant protein (5)	2.5 ± 0.2	1.8 ± 0.2	-0.6 (-1.3 to 0.04)	-0.5 (-1.1 to 0.2)
Whole grain (10)	2.1 ±0.3	2.0 ± 0.3	-0.1 (-0.6 to 0.5)	-0.2 (-0.4 to 0.8)
Dairy (10)	5.5 ± 0.3	5.6 ± 0.3	0.1 (-0.5 to 0.7)	0.2 (-0.4 to 0.8)
Fatty acids (10)	4.6 ± 0.3	4.0 ± 0.3	-0.6 (-1.4 to 0.3)	-0.6 (-1.4 to 0.3)
Sodium (10)	4.2 ± 0.4	4.1 ± 0.3	-0.1 (-1.0 to 0.7)	-0.3 (-1.2 to 0.6)
Refined grain (10)	5.4 ± 0.3	5.1 ± 0.3	-0.3 (-1.2 to 0.6)	-0.4 (-1.3 to 0.6)
Empty calories from added sugar, solid fat, and alcohol (20)	12.0 ± 0.7	9.7 ± 0.7	**-2.3 (-3.8 to -0.7)**	-1.6 (-3.5 to 0.2)

*Reference group: women with adequate sleep quality

** Adjusted for age and smoking status

Table 3.3. Total diet quality in relation to sleep problems in the past month among women within 5 years after childbirth, NHANES 2005-2008

		Diet quality			
	Prevalence of sleep problem, weighted % (SE)	With sleep problem M ± SE	Without sleep problem M ± SE	Crude model, β (95% CI)*	Adjusted model β (95% CI)**
Trouble getting asleep	17.6 (2.0)	40.8 ± 2.5	49.2 ± 1.0	**-8.4 (-13.3 to -3.5)**	**-4.5 (-8.5 to -0.4)**
Waking up during the night and have trouble getting back to sleep	20.1 (2.1)	42.6 ± 2.1	49.0 ± 1.1	**-6.4 (-11.0 to -1.9)**	**-5.2 (-9.7 to -0.7)**
Waking up too early in the morning and unable to get back to sleep	12.6 (1.9)	45.4 ± 2.0	48.1 ± 1.1	-2.7 (-6.5 to 1.1)	-2.7 (-6.4 to 1.1)
Feeling unrested during the day no matter how many hours of sleep	36.0 (3.3)	45.1 ± 1.8	49.2 ± 1.2	-4.1 (-8.2 to 0.1)	-2.9 (-7.2 to 1.4)
Feeling excessively or overly sleepy	22.7 (2.7)	43.2 ± 2.3	49.1 ± 0.9	**-5.9 (-10.2 to -1.6)**	**-5.1 (-9.4 to -0.9)**
Not enough sleep	35.7 (3.2)	44.2 ± 1.8	49.7 ± 1.2	**-5.5 (-9.4 to -1.7)**	**-5.2 (-9.3 to -1.1)**

* Reference group: women without specific sleep problem

** Adjusted for age and smoking status

CHAPTER IV

SLEEP DURATION AND EVENING SNACKING AMONG US WOMEN WITH YOUNG CHILDREN

Abstract

Background: Mothers' diets impact their health and the health of their children. Evening snacking among women with young children, especially consumption of high-calorie, high-carbohydrate snacks, may impact overall diet quality and glucose metabolism. Short sleep duration is common among women with young children and may be a potential risk factor for evening snacking.

Objective: We examined consumption of evening snacks, and energy and macronutrient consumption from evening snacks in relation to sleep duration among US women with young children.

Methods: Data were from National Health and Nutrition Examination Survey (NHANES) 2005-2012. We included women with young children, who were non-pregnant, aged 20-44 years within 5 years of childbirth, who completed two 24-hour dietary recalls, and reported ≤8 hours of sleep per night (N=943). Usual weekday/workday sleep duration was categorized as short (<7 hours) versus adequate (7-8 hours). Evening snacks were eating occasions containing foods other than solely non-caloric water between dinner and midnight. We calculated average daily energy and macronutrients (protein, total fat, carbohydrate, sugar, and fiber) consumed as evening snacks among women who reported evening snacks. Logistic and multivariable-adjusted quantile regression models estimated the association between sleep duration and evening snack consumption and composition.

Results: Short sleep duration was not associated with evening snacking among U.S. women with young children (OR=1.2, 95%CI: 0.8 to 1.7). Among women who consumed evening snacks, neither energy nor macronutrient consumption from evening snacks differed by sleep duration.

Conclusions: Short sleep duration is not associated with evening snacking among U.S. women with young children. Research may be better focused on identifying other psychosocial and behavioral risk factors for unhealthy dietary behaviors among US women with young children.

Introduction

Healthy eating habits are important for chronic disease prevention,[15] and are particularly important for women with young children as maternal eating patterns and food choices influence the development of their children's diets.[27,53] Snacking has garnered significant interest as a dietary pattern that has evolved and may be amenable to targeted interventions. Over the past 30 years, the prevalence of snacking has increased from 71% to 97% among US adults, and calories from snacks has risen from 18% to 24% of total daily energy intake over this period.[16] The timing and composition of snacks are important for energy balance and cardiometabolic health.[17–20] Evening snacking, defined as snacking occurring between dinner and bedtime,[20] is of particular interest because consuming protein or carbohydrates in the late evening can negatively impact insulin levels,[24] and has been associated with greater glucose concentration and impaired ability of insulin secretion to compensate for reduced insulin sensitivity.[19] While there are not quantitative studies to our knowledge that report the prevalence of evening snacking among U.S. women with young children, qualitative studies among women with young children indicate that many women consume evening snacks after their children go to bed which often include healthy foods, [29] which suggests that the prevalence of evening snacking in this population may be significant. Thus, evening snacking, especially consumption of high-calorie, and high-carbohydrate snacks, may be an important dietary target among women with young children. Research is scant on potential risk factors for unhealthy evening snacking among U.S. women with young children.

Short sleep duration may be a risk factor for evening snacking, especially high-calorie or high-carbohydrate snacks. Emerging evidence has linked short sleep duration to increased evening snacking behaviors among adults, through hemostatic, cognitive, emotional, and behavioral mechanisms.[89] In lab studies, experimentally shortened sleep duration led to greater energy intake the following day, particularly in the evening, largely due to increased snacking of foods with higher carbohydrate content.[33] Experimentally-induced sleep deprivation has also been associated with greater consumption of carbohydrates, protein, and fiber after dinner.[39] Previous studies have estimated that 42% of women with young children have short sleep duration, compared to 36% of U.S. adults generally.[45] Another study found that each child under the age of two has been associated with an average of 13 fewer minutes of parental sleep per day, and each child aged 2-5 years was associated with 9 fewer minutes of sleep per day.[49] Short sleep duration may be a potential risk factor for evening snacking, especially consumption of high-calorie, high-carbohydrate snacks among women with young children.

The primary objective of this study was to examine the association between sleep duration and consumption of evening snacks among a nationally representative sample of U.S. women with young children. We hypothesized that women with short sleep duration would be more likely to consume evening snacks compared to women with adequate sleep duration. The secondary objective was to examine the association between sleep duration and energy and nutrient consumption of evening snacks among women who reported consumption of evening snacks. We hypothesized that women with short sleep duration would consume more energy, total fat, and carbohydrate, and less protein and fiber from evening snacks compared to women with adequate sleep duration.

Methods

Sample and Survey Administration

Data from the National Health and Nutrition Examination Survey (NHANES) 2005-2012 was used for this study. NHANES employs a complex multi-stage probability cluster design,[54] including a nationally representative sample of non-institutionalized Americans.[71] Data was collected through in-person interviews at their homes and at a Mobile Examination Center (MEC) and subsequently a follow-up interview via phone. Full details of the sampling methodology and data collection procedures are available.[54] Because NHANES started collecting information on sleep duration from 2005-2006, we combined the most recent four waves of NHANES data: 2005-2006, 2007-2008, 2009-2010, and 2011-2012. Eligibility criteria included non-pregnant women, aged 20 to 44 years old, who delivered their youngest child within the past 5 years, completed two 24-hour dietary recalls, and reported ≤8 hours of sleep per night. We only included women 20-44 years because the reproductive health information – including pregnancy status – was available only for women within this age range in the public-use dataset. The University of Massachusetts Medical School Institutional Review Board deemed this study exempt from human subject research oversight.

Sleep Duration

Participants' usual sleep duration was assessed during the home interview by asking "How much sleep do you usually get at night on weekdays or workdays?" Participants reported their usual sleep duration as an integer number of hours of sleep per night. We categorized usual sleep duration as short (<7 hours) and adequate (7-8 hours), consistent with previous research.[45] We excluded women who didn't report sleep duration, who answered "don't know" to the question about usual sleep duration, and women reporting >8 hours per night (long sleep duration) from the analytic sample. We excluded women with long sleep duration because our main aim is to examine whether short sleep duration is a risk factor for evening snacking in this population, considering high prevalence of short sleep duration among women with young children,[35] and its association with several negative health consequences[105–107] and greater snacking among adults generally.[89] The mechanisms linking long sleep duration and eating behaviors are not well established,[32,34] and we had no a priori hypothesis regarding the association between long sleep duration and evening snacking. Thus, we focus this investigation on the comparison between women with short versus adequate sleep duration.

Evening Snacking

Participants completed two 24-hour dietary recalls, the first at the MEC, and the second on the phone 3 to 10 days later. During both interviews, participants listed types and amounts of food they consumed from midnight to midnight on the previous day. We first calculated dinnertime on each dietary recall. During the dietary interviews, women reported the time and name (e.g., breakfast, lunch, dinner, snack, and beverage) of each eating occasion in English or Spanish. For each recall, dinnertime was categorized as the eating occasion times reported as “supper”, “dinner”, or “cena” (Spanish). If a woman didn’t report dinner on a recall, dinnertime was assigned as 6pm because 6pm is a common dinner time for women with young children.[45] Evening snacking was defined as any eating occasions after dinner until midnight (i.e., the end of that dietary recall). Participants labeled these eating occasions as snacks or beverages, or the equivalent words in Spanish. Eating occasions composed solely of non-caloric water were not categorized as evening snacks. Women reporting evening snacks on either dietary recall day were categorized as evening snackers, as has been done in other studies characterizing snacking using dietary recalls.[16] Among women who consumed evening snacks, we calculated average daily energy (kcal/day) and macronutrient (grams/day; protein, carbohydrate, total fat, sugar, and fiber) consumption from evening snacks as the average from all evening snacks over the two days, similar to previous research.[16] For example, a woman consuming 200 kcal on day 1 and 300 kcal on day 2 had an average daily energy intake of 250 kcal/day from evening snacks.

Potential confounders

We considered participants’ demographic, behavioral, and psychosocial characteristics as potential confounders due to observed associations with sleep duration[52,73–77] and snacking[74,78–81] among adults generally. Variables were self-reported except for height and weight, which were measured at MEC. Participant's age was grouped as 20-24 years, 25-29 years, 30-34 years, 35-39 years, and 40-44 years. We categorized race/ethnicity as non-Hispanic White, non-Hispanic Black, Mexican-American/Hispanic, and other race/ethnicity (including multi-racial). Education level included less than high school, high school graduate/GED, some college/Associate's degree, and college graduate or higher. Marital status was categorized married or living with partner, widowed/separated/divorced, and never married. Household poverty income ratio (PIR) is the ratio of self-reported household income to poverty threshold for a household of that size, and was categorized as <100% Federal Poverty Level (FPL), 100-300% FPL, and >300% FPL. Household food security was assessed using 18 questions from the US Food Security Survey Module. Based on the number of affirmative responses, household food security was categorized by NHANES as full (0 affirmative responses), marginal (1-2), low (3-7) and very low (8-18) food security.[82] Body mass index (BMI; kg/m^2) was calculated from measured height and weight and was categorized as underweight ($<18.5\ kg/m^2$), normal weight ($18.5 \leq BMI < 25.0\ kg/m^2$), overweight ($25.0 \leq BMI < 30.0\ kg/m^2$), and obese ($BMI \geq 30.0\ kg/m^2$).[84] Participants were asked whether they have smoked 100 or more cigarettes in their lives and whether they smoke currently, and smoking status was categorized as current, former, and never. Participants' physical activity level was calculated from the frequency and duration of various physical activities in a typical week. If they engaged in 150 minutes or more of moderate-intensity activity per week, they were recognized as following physical activity guidelines.[83] The 9-item Patient Health Questionnaire (PHQ-9) was used to assess the frequency of depressive symptoms over the past 2 weeks,[108] with a global score ranging from 0 to 27 where high scores indicate elevated depressive symptoms. This measure is commonly used to screen adults for depressive symptoms in the primary care setting.[87] Participants who scored 10 or higher on the PHQ-9 were considered to have elevated depressive symptoms.[56]

Statistical Analyses

All statistical analyses accounted for sample weights and the complex survey design; results are representative of U.S. non-pregnant women aged 20-44 years who gave birth within the past 5 years. As recommended in the NHANES analytic guidelines,[85] we created a combined 8-year weight by assigning one-fourth of the 2-year weight for each survey wave (2005-2006, 2007-2008, 2009-2010, and 2011-2012).

We used regression models to examine evening snacking in relation to sleep duration. For all models, women with adequate sleep duration (7-8 hours/night) served as the reference group. We used logistic regression models to estimate the association between sleep duration and consumption of evening snacks. Because average daily consumption of energy and macronutrients from evening snacks were not normally distributed, we used quantile regression models to compare the median daily consumption of energy and macronutrients from evening snacks in relation to sleep duration. The resulting β coefficient represents the difference in the median level of daily energy and macronutrient consumption from evening snacks comparing women with short sleep duration to women with adequate sleep duration.[29] We adjusted for confounding using multivariable adjustment. Potential confounders were identified if at least one level of the variable was associated with any of the snacking outcomes at $p < 0.05$ using a complete case sample excluding participants missing information on that confounder and were included in the adjusted model. We redefined our final analytic sample only including eligible women without missing information on covariates that were included in the adjusted model. The same set of covariates was included in all multivariable adjusted models for all snacking outcomes to aid interpretation of results.

We performed sensitivity analyses to assess the robustness of our results to analytic decisions. First, we repeated the main analyses excluding women who did not report dinner on one or both recalls. Second, because dietary data was collected from midnight to midnight on a single calendar day, any evening snacks consumed between midnight and bedtime would not be captured. Thus, we conducted a sensitivity analysis in which we included eating occasions between 12am and 4am in our assessment of evening snacks. While within a recall day, eating occasions during this time frame reflect food intake before the woman’s night sleep, assuming that the timing of women’s eating occasions and sleep are relatively consistent day-to-day, these eating occasions can approximate snacks not captured due to the calendar-day period of the dietary recalls. We chose 4am as the latest time for evening snacks because conceptually we were interested in evening snacks, i.e., snacks consumed after dinner and before bedtime, and we considered that food consumed after 4am to be morning snacks rather than evening snacks. All analyses were conducted using SAS (Version 9.3, SAS Institute Inc., Cary, NC).

Results

Study sample inclusion and exclusion

NHANES 2005-2012 included 1,187 non-pregnant women aged 20 to 44 years old who delivered their youngest child within the previous 5 years. We excluded women missing information on sleep duration (n=4) or who reported average weekday/workday sleep duration of over 8 hours/night (n=79), and who did not complete the first (n=29) or second dietary recall (n=171), resulting in an analytic sample of 943 women. These women represent 11.8 million women with young children nationally.

Overall sample characteristics

Women were on average 30.7 years old (SE: 0.3). One third of women had given birth within the past year, 21.6% 1-2 years ago, 16.5% 2-3 years ago, 16.9% 3-4 years ago, and 11.7% 4-5 years ago. Other characteristics of the sample are shown in Table 4.1. Thirty-eight percent (37.9%) of women had short sleep duration and 62.1% had adequate sleep duration.

Sleep duration and evening snacking

Fifty-two percent of women reported evening snacking on the first dietary recall and 46.5% reported evening snacking on the second; 68.5% reported evening snacking on one or both days. Seventy-one percent of women with short sleep duration and 67.1% of women with adequate sleep reported evening snacks; consumption of evening snacks did not differ by sleep duration (crude OR=1.2, 95%CI: 0.8 – 1.7). As consumption of evening snacks did not differ by any participant characteristics, we did not include any characteristics in a multivariable-adjusted regression model.

Sleep duration and energy and macronutrient consumption

Among women who consumed evening snacks, 39.9% had short and 60.1% had adequate sleep duration. The median average daily energy consumed as evening snacks was 168.8 kcal/day for women with short duration and 157.5 kcal/day for women with adequate sleep duration (Table 4.2). Neither the median average daily energy consumed as evening snacks nor the average daily consumption of protein, carbohydrate, fat, sugar, and fiber consumed as evening snacks differed by sleep duration (Table 4.2).

Sensitivity analyses

We performed sensitivity analyses to assess the robustness of our results to analytic decisions. Frist, we performed a sensitivity analysis excluding the 6% and 7% of women who didn’t report dinner on dietary recall day 1 or day 2, respectively; results were consistent with the main analyses in which we assigned them a dinner time of 6pm (data not shown). Second, in sensitivity analyses of snacking between midnight and 4am, 24 women reported snacks between midnight and 4am on dietary recall day 1, and 18 women on day 2; 36 women on either dietary recall day. When including these eating occasions in our assessment of eating snacks, categorization of consumption (yes/no) of evening snacks only changed for 6 women, and results of consumption of evening snacks and energy and macronutrient composition of evening snacks were consistent to the main analyses (results not shown).

Discussion

Among US women with young children, short sleep duration was not associated with the consumption of evening snacks, and among women who consumed evening snacks, neither energy intake from nor nutrient consumption of evening snacks differed by sleep duration. Our finding that consumption of evening snacks did not differ by sleep duration is consistent with a prior NHANES study of sleep duration and eating behaviors among U.S. adults generally.[45] This study found that 66% of adults with short sleep duration and 64% of adults with adequate sleep duration reported snacks after dinner on the first dietary recall, with no differences by sleep duration.[45] Although previous research suggested that evening snacking may be an important issue among women with young children,[29] we found nearly identical prevalence of evening snacking among U.S. women with young children as among U.S. adults generally.[45] Thus, evening snacking may not be a bigger issue among women with young children than among U.S. adults generally. Our study findings were not consistent with findings from prior laboratory studies, where sleep deprivation was associated with greater evening snacks.[34,39,40,88] Laboratory studies have indicated that staying awake at night may lead to physiological changes that promote hunger and increase tendency to eat.[39,88] In one laboratory study that imposed sleep restriction of 5 hours per night for 5 consecutive days, participants consumed more calorie from after-dinner snacks, and these snacks included more carbohydrate and protein than intake on days following unrested sleep.[39] In another study, sleep restriction of 5.5 hours per night for 14 days contributed to greater energy intake from snacks, especially during the period of 7pm to 7am with higher carbohydrate content.[33] Additionally, a decrease in leptin level following sleep restriction was associated with an increased appetite for sweet, salty, and starchy foods.[109] There are several differences between these previous experimental studies and the present population-based study. First, sleep conditions were different. In experimental studies, individual have usual adequate sleep duration and sleep deprivation was induced under experimental condition; while in the present study, women with young children slept under their usual condition with either short or adequate usual sleep duration. Second, study populations differed. Individuals who have time to participate in a 14-day experimental sleep study are not representative of U.S. adults generally. Third, the measurement of snack consumption differed. In experimental studies, individuals were provided with unlimited access to snacks with various snack options.[33] Items consumed were weighted, and disappearance from inventory was recorded, which provides an accurate measure of consumption of snack items; although we don't know if their snack consumption in the lab is the same as their snack consumption in their real lives. In the present study, snack consumption was self-reported during two 24-hour dietary recalls. Due to social desirability, individuals with a high intake of supposedly unhealthy snacks may be tempted to under report their snack consumption.[61] Individuals' personalities may also contribute to the differences between their reported snack consumption over two dietary recalls and their actual average intake.[61]However, these biases in reporting are not expected to differ by sleep duration, and thus this nondifferential measurement error is expected to bias the study results towards the null. Fourth, experimental studies measured the acute effects of sleep deprivation on increased appetite and consumption of snacks.[33,39] In the present study, we do not have information on sleep duration on the night preceding each dietary recall, and it is possible that some women reporting that their usual weekday/workday sleep duration was <7 hours/night (short sleep duration) slept longer the night preceding their dietary recall. Although experimental sleep deprivation may result in greater energy intake from evening snacks, women may change their eating behaviors to accommodate the physiological effect of chronic inadequate sleep duration, which may explain why experimental studies of shortened sleep observed greater snacking while we did not observe a difference in evening snacking between women with short and adequate sleep duration. Future research should compare dietary intake in relation to previous night's sleep to examine whether there is an acute effect of shortened sleep on evening snacking among community-dwelling U.S. women with young children. As data from two 24-hour dietary recalls may not be sufficient to estimate individuals' long-term dietary intake, future population-based studies of sleep duration and long-term snacking behaviors may consider using Food Frequency Questionnaires (FFQs) to estimate the association between chronic sleep deprivation and chronic dietary patterns. FFQs evaluate person's usual intake over a defined period of time,[61] which may be a good alternative to measure long-term dietary intake if properly adjusting for underreporting of daily energy consumption.

The present study has additional strengths and limitations. Using data of a large nationally representative survey enables us to generalize study results to non-institutionalized US women who gave birth within the past 5 years and are not currently pregnant. Dietary recall data was collected by trained interviewers. Because dietary data was collected as women's food consumption per calendar day, i.e., from midnight to midnight, snacking after midnight but before going to bed won't be captured. Conceptually we are interested in snacks between dinner and bedtime, i.e., evening snacks.[20] It is possible that women with short sleep duration go to bed late and consume snacks after midnight. We conducted a sensitivity analysis exploring this possibility by including snacks consumed between midnight and 4am as evening snacks, and results were consistent with the main analyses, suggesting that it is unlikely that the lack of data on snacks possibly consumed between midnight and bedtime explain our results. Future research into evening snacks should extend dietary recalls until bedtime, even if that extends into the following calendar day, so as to collect data to answer this question. Finally, because data were cross-sectional, we are unable to make causal inferences.

Conclusions

Research examining the eating habits among women with young children is limited. We found that sleep duration was not associated with the consumption of evening snacks, or energy and macronutrient consumption from evening snacks among women who consumed evening snacks. Future research may consider examining dietary intake in relation to previous night's sleep in order to elucidate the role of acute sleep deprivation among community-dwelling women with young children. Research may also be better focused on identifying other psychosocial and behavioral risk factors for unhealthy dietary behaviors including evening snacking among U.S. women with young children.

Table 4.1. Characteristics of US women with young children, NHANES 2005-2012, Mean ± SE or weighted % (95% CI)

Sample N	943
Weighted N	11,785,427
Age, Mean (SE)	30.7 (0.3)
Age categories	
20-24 years	18.8 (15.4 – 22.1)
25-29 years	23.6 (19.8 – 27.4)
30-34 years	28.1 (23.9 – 32.2)
35-39 years	22.0 (17.2 – 26.9)
40-44 years	7.6 (5.7 – 9.4)
Years since most recent live birth	
Within one year	33.3 (29.1 – 37.5)
Within 1-2 years	22.1 (18.4 – 25.8)
Within 2-3 years	16.2 (12.6 – 19.8)
Within 3-4 years	16.7 (12.9 – 20.6)
Within 4-5 years	11.7 (8.6 – 14.8)
Race/ethnicity	
Non-Hispanic White	60.9 (55.0 – 66.7)
Non-Hispanic Black or African American	13.1 (9.9 – 16.2)
Mexican-American/Hispanic	20.8 (16.6 – 25.0)
Other race/ethnicity (including multi-racial)	5.2 (3.2 – 7.2)
Education level	
Less than high school	18.0 (14.4 – 21.5)
High school graduate/GED	22.5 (18.6 – 26.4)
Some college/Associate's degree	32.3 (28.4 – 36.1)
College graduate or higher	27.3 (22.3 – 32.3)
Poverty income ratio (PIR)	
<100% FPL	22.7 (19.4 – 25.9)
100-300% FPL	41.6 (37.4 – 45.8)
>300% FPL	35.7 (30.8 – 40.6)
Marital status	
Married or living with someone	79.8 (75.8 – 83.7)
Separated or widowed or divorced	6.9 (5.3 – 8.4)
Never married	13.3 (10.0 – 16.7)
Smoking status	
Never smoker	62.5 (58.4 – 66.7)
Former smoker	22.8 (18.8 – 26.8)
Current smoker	14.7 (11.1 – 18.3)
Weight status	
Underweight	2.2 (0.7 – 3.7)
Normal weight	35.1 (30.5 – 39.7)
Overweight	27.9 (23.6 – 32.3)

Obese	34.8 (30.3 – 39.2)
Household food security	
Full	69.1 (64.9 – 73.3)
Marginal	12.3 (9.8 – 14.7)
Low or very low	18.6 (15.3 – 22.0)
Household size, Mean (SE)	4.2 (0.1)
Household size	
Two	4.4 (2.7 – 6.1)
Three	29.4 (26.0 – 33.7)
Four	30.0 (26.1 – 34.0)
Five or more	36.2 (31.6 – 40.8)
Depressive symptoms, Mean (SE)	3.6 (0.2)
Elevated depressive symptoms	12.0 (9.1 – 14.9)
Meeting physical activity guideline	31.2 (25.9 – 36.4)

Abbreviations: federal poverty level (FPL)
Missing data for poverty income ratio (n=65), weight status (n=2), household food security (n=5), depressive symptoms (n=2), physical activity (n=187, due to no data collection in NHANES 2005-06).

Table 4.2. Average energy and macronutrient consumption from evening snacks over two days, in relation to sleep duration, among US women with young children who reported evening snacking, NHANES 2005-2012

	Short sleep duration	Adequate sleep duration
Energy (kcal/day), median (IQR)	167.5 (80.5 – 302.5)	156.5 (74.0 – 279.5)
Crude beta (95% CI)	11.0 (-21.0 to 43.0)	(Reference)
Adjusted beta (95% CI)**	8.7 (-24.1 to 41.5)	(Reference)
Protein (grams/day), median (IQR)	2.7 (0.9 – 6.8)	2.8 (1.0 – 5.9)
Crude beta (95% CI)	-0.1 (-0.9 to 0.8)	(Reference)
Adjusted beta (95% CI)**	-0.01 (-0.9 to 0.7)	(Reference)
Carbohydrate (grams/day), median (IQR)	24.9 (11.5 – 41.6)	22.0 (10.9 – 41.3)
Crude beta (95% CI)	2.9 (-1.2 to 5.9)	(Reference)
Adjusted beta (95% CI)**	2.0 (-1.5 to 5.9)	(Reference)
Total fat (grams/day), median (IQR)	5.1 (1.3 – 10.7)	4.2 (1.0 – 9.1)
Crude beta (95% CI)	0.8 (-0.5 to 1.8)	(Reference)
Adjusted beta (95% CI)**	0.2 (-0.8 to 1.6)	(Reference)
Sugar (grams/day), median (IQR)	14.4 (5.3 – 25.2)	14.4 (6.2 – 26.1)
Crude beta (95% CI)	0.04 (-3.7 to 3.6)	(Reference)
Adjusted beta (95% CI)**	-0.4 (-3.5 to 3.4)	(Reference)
Fiber (grams/day), median (IQR)	0.8 (0.2 – 2.0)	0.7 (0.2 – 1.7)
Crude beta (95%CI)	0.1 (-0.5 to 0.5)	(Reference)
Adjusted beta (95% CI)	0.1 (-0.3 to 0.7)	(Reference)

** Adjusted for race/ethnicity and education level

CHAPTER V

DISCUSSION AND CONCLUSIONS

Summary of Findings

The purpose of this dissertation was to examine the association between sleep duration and sleep quality with diet quality and evening snacking among U.S. women with young children.

We first examined the association between sleep duration and diet quality among women with young children. We found that US women with young children have, on average, poor diet quality and the majority fails to follow current recommendations for having a good quality diet. Neither short nor long sleep duration was associated with diet quality in this population.

Second, we examined whether sleep quality was associated with diet quality among women with young children. As an exploratory aim, we examined the associations between overall sleep quality and components of diet quality, and explored whether poor sleep quality mediated the association between elevated depressive symptoms and diet quality. We found that overall poor sleep quality was associated with poorer diet quality among women with young children. Four specific sleep problems examined - having trouble getting to sleep, waking up during the night and having trouble returning to sleep, feeling sleepy, and not getting enough sleep – were also associated with poorer diet quality. Poor sleep quality partially mediated the association between elevated depressive symptoms and diet quality.

Third, we examined the association between sleep duration and evening snacking among women with young children. We found that among US women with young children, short sleep duration was not associated with the consumption of evening snacks. Among women who consumed evening snacks, neither energy intake from nor nutrient consumption of evening snacks differed by sleep duration.

In summary, among US women with young children, sleep duration was not associated with diet quality or the consumption of evening snacks. Overall poor sleep quality was associated with poorer diet quality; and specifically four aspects of sleep quality – having trouble getting to sleep, waking up during the night and having trouble returning to sleep, feeling sleepy, and not getting enough sleep – were associated with poorer diet quality.

Study Strengths and Limitations

Several strengths of this dissertation are worth noting. Using data from a large nationally representative survey enabled us to generalize results to non-institutionalized US women aged 20-44 years who gave birth within the past 5 years and are not currently pregnant. Dietary information was collected by trained interviewers throughout the data collection period. The HEI-2010 is a valid and reliable measure of diet quality based on two dietary recalls,[14] which allows analysis of overall and component diet quality. Both height and weight were measured rather, which overcome the potential bias of overestimation of self-reported height and underestimation of self-reported weight and thus body mass index.[110] Additionally, many potential confounders were assessed using validated scales. Depressive symptoms were measured by the PHQ-9, which is a reliable and valid measure for depression severity[86] and has been used as a screening tool for post-partum depression[56] and among adults generally in the primary care setting.[87] The level of physical activity was measured by the questions included in the Global Physical Activity Questionnaire, which has shown moderate-strong association with the previously validated International Physical activity Questionnaire and has been a suitable and acceptable instrument for monitoring physical activity.[111] Household food security was measured using the 18-item US Food Security Survey Module, an instrument developed by the United States Department of Agriculture[82] and used in several studies.[112,113]

There are also several limitations of this dissertation. Although 24 hour dietary recall has been used as a reference instrument of dietary intake, it suffered from intake-related bias and person-specific bias.[61] These biases are not expected to be differential which may bias the study results towards to null. As mentioned above, two 24-hour dietary recalls may not provide a better estimation of individuals' usual and long-term dietary.[66] Future population-based studies may use food frequency questionnaires (FFQs) as alternatives to quantify individuals' chronic dietary intake in relation to chronic sleep deprivation and poor sleep quality. Because dietary data was collected as women's food consumption per calendar day, i.e., from midnight to midnight, in the third study, snacking after midnight but before going to bed won't be captured. Conceptually we are interested in snacks between dinner and bedtime, i.e., evening snacks.[20] It is possible that women with short sleep duration go to bed late and consume snacks after midnight. However, we conducted a sensitivity analysis exploring this possibility by including snacks consumed between midnight and 4am as evening snacks, and results were consistent with the main analyses, suggesting that it is unlikely that the lack of data on snacks possibly consumed between midnight and bedtime explain our results. Sleep duration was self-reported as an integer number of hours of sleep at night on weekdays or workdays. It is possible that women's weekend sleep duration may differ from their weekday or workday sleep duration. Not taking women's weekend sleep duration into account may introduce nondifferential measurement error which may bias the results towards the null. Women may count time in bed as actual time they spent in sleeping, which may also introduce nondifferential measurement error. Additionally, sleep duration was recorded as integer numbers in NHANES. The rounding of sleep duration to the nearest integer hour may overestimate sleep duration and results in misclassification, particularly of women with short sleep duration as having adequate sleep duration. Although nondifferential measurement error exists in the self-reported measurement of sleep duration, it is moderately correlated with sleep duration measured with actigraphy.[67] Self-reported sleep duration has been significantly associated with measures of health, including nutrient intake,[44] eating behaviors,[45] and obesity.[114] Although the sleep quality measure in NHANES has not been validated against objectively measured sleep quality, previous studies have observed significant associations between this measure of sleep quality and several measures of health, including pre-diabetes,[99] inflammation,[101] and hypertension.[72] We were unable to adjust for other variables previously found to impact both sleep and diet behaviors, such as current breastfeeding behaviors,[102–104] as these data were not collected in NHANES. To the extent that breastfeeding is associated with poorer sleep quality[103] and better diet quality,[104] failure to adjust for breastfeeding behaviors may underestimate the association between poor sleep quality and poor diet quality and bias the result towards the null. Lastly, because data were cross-sectional, we were unable to draw causal inferences between sleep duration and quality with diet quality and evening snacking.

Discussion and Future Research Directions

Among U.S. women with young children, neither short nor long sleep duration as associated with diet quality; short sleep duration was not associated with evening snacking either, which did not confirm results from prior experimental and epidemiological studies.[34,39,40,88] There are several possibilities for the null findings. First, as mentioned above, the null findings may be due to measurement error of sleep duration or dietary intake. Second, differences exist between experimental studies and the present population-based study. In experimental studies, individuals have usual adequate sleep duration and sleep deprivation was induced under experimental conditions; while in the present study, women with young children slept under their usual condition with either short or adequate usual sleep duration. Study population also differed. Individual participants in the experimental studies are required to sleep in the lab; they are not representative of U.S. adults generally. The measurement of eating behaviors and snack consumption also differed. Individuals were provided with unlimited access to snacks in experimental studies. Items consumed were weighted, and disappearance from inventory was recorded, which provides an accurate measure of consumption of snack items;

however, we don't know if snack consumption in the lab is reflective of snack consumption in the real world. Although experimental sleep deprivation may result in greater energy intake from evening snacks, women may change their eating behaviors to accommodate the physiological effect of chronic inadequate sleep duration. Additionally, although sleep deprivation contributes to increased appetite for snacks in experimental studies, it may only affect women's eating habits right after their short sleep or in the following day; we do not have information on women's sleep duration on the night preceding each dietary recall. Future research should compare dietary intake in relation to previous night's sleep to examine whether there is an acute effect of shortened sleep on evening snacking and diet quality among community-dwelling U.S. women with young children.

More than half (55%) of U.S. women with young children reported poor sleep quality. Overall poor sleep quality was associated with poorer diet quality and four specific aspects of sleep quality problems- having trouble getting to sleep, waking up during the night and having trouble returning to sleep, feeling sleepy, and not getting enough sleep- were associated with poorer diet quality as well. Emerging evidence has linked disrupted sleep to increased food intake[88] and poorer diet quality[89] through homeostatic and non-homeostatic pathways.[89] Poor sleep quality is associated with decreases in leptin levels and increases in ghrelin levels,[34,40] which may impact appetite regulation,[41] and stimulate the consumption of energy-dense foods [42,43] and consequently poorer diet quality [34,37] and higher energy intake.[34,44] Poor sleep quality may also be associated with impairments in executive functioning through the impairments in the pre-frontal cortex.[89] In adults, weaker executive control is related to a greater consumption of snacks and high-fat food and lower consumption of fruit and vegetables,[90] which may contribute to poorer diet quality. Future research is needed to examine whether improvement in sleep quality may contribute to improvement in maternal diet quality, which has the potential to improve both maternal and children's health.

Because of short sleep duration and poor sleep quality as common symptoms of depression,[68] and the positive association between elevated depressive symptoms and unhealthful diet among post-partum women,[70] we explored whether short sleep duration (Aim 1) and poor sleep quality (Aim 2) mediated the association between elevated depressive symptoms and diet quality. We found that elevated depressive symptoms was not associated with short sleep duration. Short sleep duration did not mediate the association between elevated depressive symptoms and poor diet quality either. Elevated depressive symptoms was significantly associated with poor sleep quality, and poor sleep quality might mediate the association between elevated depressive symptoms and poor diet quality. In both aims we found that women with elevated depressive symptoms had poorer diet quality compared to women without elevated depressive symptoms. Elevated depressive symptoms may affect diet quality through the pathway of poor sleep quality, rather than short sleep duration. Given the negative consequences of elevated depressive symptoms for women and their children,[95] treating depression is a priority for women with young children who exhibit elevated depressive symptoms. Treatment for depression should include sleep quality assessment, and improving sleep in depressed patients is found to improve mental health outcomes.[96] Thus, treating depression among women with young children may not only provide great benefit for their mental health, but may also have a collateral positive impact on their diet quality, to the extent that depressive symptoms directly affect eating behaviors and thus diet quality.

An emerging body of research established impaired sleep as a novel risk factor for weight gain and obesity. Short sleep duration has been associated with weight gain[41] and development of obesity,[115] particularly among young adults. Researchers speculated that chronic sleep deprivation may lead to weight gain via influence on diet and eating behaviors.[41] This dissertation found that sleep duration is not associated with diet quality or evening snacking behaviors. This suggests that rather than impacting diet quality, short sleep duration may lead to weight gain via increased calorie consumption. As discussed above, it may also be that short sleep duration may have a more acute impact on dietary intake, with more effect on the next day's intake. Future research is needed to examine whether excessive calorie intake mediates the association between short sleep duration and weight gain and the development of obesity and to examine the association between the previous night of sleep and dietary intake in the following day among community-dwelling w. This dissertation also confirms the hypothesis that overall poor sleep quality is associated with poorer diet quality. Studies examining the association between sleep quality and diet quality should further explore whether improvement in sleep quality may contribute to improvement in diet quality among women with young children, which is important for both maternal and child cardiometabolic health.

Overall, the findings of this dissertation further our understanding of the association between sleep duration and quality with diet quality and evening snacking among U.S. women with young children. Given the important impact of women's diet quality and eating behaviors on children's eating habits and the relatively high prevalence of short sleep duration and sleep problems among women with young children, this dissertation provides information useful for informing the direction of future research of dietary quality and eating behaviors of women with young children. Future studies are needed to explore whether improvement in sleep quality may contribute to improvement in diet quality among women with young children. Research is also needed to identify other psychosocial and behavioral factors that may negatively affect healthy dietary behaviors in this population, in order to inform approaches to help women improve their health and their children's health.

REFERENCES

1. Ye EQ, Chacko SA, Chou EL, Kugizaki M, Liu S. Greater Whole-Grain Intake Is Associated with Lower Risk of Type 2 Diabetes , Cardiovascular Disease , and Weight Gain. *J Nutr*. 2012;142(7):1304–1313. doi:10.3945/jn.111.155325.both.

2. Carter P, Gray LJ, Troughton J, Khunti K, Davies MJ. Fruit and vegetable intake and incidence of type 2 diabetes mellitus: systematic review and meta-analysis. *Bmj*. 2010;341(aug18 4):c4229–c4229. doi:10.1136/bmj.c4229.

3. Hu FB, Stampfer MJ, Rimm EB, et al. Dietary fat and coronary heart disease: a comparison of approaches for adjusting for total energy intake and modeling repeated dietary measurements. *Am J Epidemiol*. 1999;149(6):531–540.

4. Aburto NJ, Ziolkovska A, Hooper L, Elliott P, Cappuccio FP, Meerpohl JJ. Effect of lower sodium intake on health: systematic review and meta-analyses. *BMJ*. 2013;346(April):f1326. doi:10.1136/bmj.f1326.

5. Malik VS, Schulze MB, Hu FB. Intake of sugar-sweetened beverages and weight gain: a systematic review. *Am J Clin Nutr*. 2006;84(2):274–88.

6. Hu FB, Malik VS. Sugar-sweetened beverages and risk of obesity and type 2 diabetes: epidemiologic evidence. *Physiol Behav*. 2010;100(1):47–54. doi:10.1016/j.physbeh.2010.01.036.

7. Wirt A, Collins CE. Diet quality--what is it and does it matter? *Public Health Nutr*. 2009;12(12):2473–92. doi:10.1017/S136898000900531X.

8. U.S. Department of Agriculture, U.S. Department of Health and Human Services. *Dietary Guidelines for Americans*.; 2010.

9. McCullough ML, Feskanich D, Stampfer MJ, et al. Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. *Am J Clin Nutr*. 2002;76(6):1261–71.

10. Fung TT, van Dam RM, McCullough M, Hu FB. A Prospective Study of Overall Diet Quality and Risk of Type 2 Diabetes in Women. *Diabetes Care*. 2007;30(7):1753–1757. doi:10.2337/dc06-2581.Abbreviations.

11. Wolongevicz DM, Zhu L, Pencina MJ, et al. Diet quality and obesity in women: the Framingham Nutrition Studies. *Br J Nutr*. 2013;103(8):1223–1229. doi:10.1017/S0007114509992893.Diet.

12. Kant AK, Leitzmann MF, Park Y, Hollenbeck A, Schatzkin A. Patterns of Recommended Dietary Behaviors Predict Subsequent Risk of Mortality in a Large Cohort of Men and Women in the United States. *J Nutr*. 2009;139:1374–1380. doi:10.3945/jn.109.104505.reported.

13. Wang DD, Leung CW, Li Y, et al. Trends in Dietary Quality Among Adults in the United States, 1999 Through 2010. *JAMA Intern Med*. 2014;174(10):1587–1595. doi:10.1001/jamainternmed.2014.3422.

14. Guenther PM, Kirkpatrick SI, Reedy J, et al. The Healthy Eating Index-2010 Is a Valid and Reliable Measure of Diet Quality According to the 2010 Dietary Guidelines for Americans. *J Nutr*. 2014;(C):1–9. doi:10.3945/jn.113.183079.The.

15. Centers for Disease Control and Prevention. Physical activity and good nutrition: essential elements to prevent chronic diseases and obesity 2008. *Nutr Clin Care*. 2008;6(3):135–138.

16. Piernas C, Popkin BM. Snacking increased among U.S. adults between 1977 and 2006. *J Nutr*. 2010;140(2):325–332. doi:10.3945/jn.109.112763.

17. Barnes TL, French S a., Harnack LJ, Mitchell NR, Wolfson J. Snacking Behaviors, Diet Quality, and Body Mass Index in a Community Sample of Working Adults. *J Acad Nutr Diet*. 2015;115(7):1117–1123. doi:10.1016/j.jand.2015.01.009.

18. Nicklas T a, O'Neil CE, Fulgoni III VL. Snacking patterns, diet quality, and cardiovascular risk factors in adults. *BMC Public Health*. 2014;14(1):388. doi:10.1186/1471-2458-14-388.

19. Chandler-Laney P, Schneider C, Gower B, Granger W, MS M, JR B. Association of late-night carbohydrate intake with glucose tolerance among pregnant African American women. *Matern Child Nutr*. 2015;Epub.

20. Gallant a. R, Lundgren J, Drapeau V. The night-eating syndrome and obesity. *Obes Rev*. 2012;13(6):528–536. doi:10.1111/j.1467-789X.2011.00975.x.

21. Kinsey A, Ormsbee M. The Health Impact of Nighttime Eating: Old and New Perspectives. *Nutrients*. 2015;7(4):2648–2662. doi:10.3390/nu7042648.

22. Romon M, Edme JL, Boulenguez C, Lescroart JL, Frimat P. Circadian variation of diet-induced thermogenesis. *Am J Clin Nutr*. 1993;57(4):476–480.

23. de Castro JM. The time of day of food intake influences overall intake in humans.

J Nutr. 2004;134(1):104–111.

24. Kinsey AW, Eddy WR, Madzima T a, et al. Influence of night-time protein and carbohydrate intake on appetite and cardiometabolic risk in sedentary overweight and obese women. *Br J Nutr*. 2014;112(3):320–7. doi:10.1017/S0007114514001068.

25. Olson CM. Tracking of food choices across the transition to motherhood. *J Nutr Educ Behav*. 2005;37:129–136.

26. Walker FR, Brogan A, Smith R, Hodgson DM. A profile of the immediate endocrine, metabolic and behavioural responses following a dual exposure to endotoxin in early life. *Physiol Behav*. 2004;83(3):495–504. doi:10.1016/j.physbeh.2004.08.030.

27. Laster LER, Lovelady C a, West DG, et al. Diet quality of overweight and obese mothers and their preschool children. *J Acad Nutr Diet*. 2013;113(11):1476–83. doi:10.1016/j.jand.2013.05.018.

28. George GC, Milani TJ, Hanss-Nuss H, Freeland-Graves JH. Compliance with dietary guidelines and relationship to psychosocial factors in low-income women in late postpartum. *J Am Diet Assoc*. 2005;105(6):916–26. doi:10.1016/j.jada.2005.03.009.

29. Chang MW, Nitzke S, Guilford E, Adair CH, Hazard DL. Motivators and barriers to healthful eating and physical activity among low-income overweight and obese mothers. *J Am Diet Assoc*. 2008;108(6):1023–1028.

doi:10.1016/j.jada.2008.03.004; 10.1016/j.jada.2008.03.004.

30. Birch LL. Development of food acceptance patterns in the first years of life. *Proc Nutr Soc*. 1998;57:617–624. doi:10.1079/PNS19980090.

31. Ashman AM, Collins CE, Hure AJ, Jensen M, Oldmeadow C. Maternal diet during early childhood, but not pregnancy, predicts diet quality and fruit and vegetable acceptance in offspring. *Matern Child Nutr*. 2014:n/a–n/a. doi:10.1111/mcn.12151.

32. Kim S, DeRoo L a, Sandler DP. Eating patterns and nutritional characteristics associated with sleep duration. *Public Health Nutr*. 2011;14(5):889–95. doi:10.1017/S136898001000296X.

33. Nedeltcheva A V., Kilkus JM, Imperial J, Kasza K, Schoeller D a., Penev PD. Sleep curtailment is accompanied by increased intake of calories from snacks. *Am J Clin Nutr*. 2009;89(1):126–133. doi:10.3945/ajcn.2008.26574.

34. Stern JH, Grant AS, Thomson C a, et al. Short sleep duration is associated with decreased serum leptin, increased energy intake and decreased diet quality in postmenopausal women. *Obesity (Silver Spring)*. 2014;22(5):E55–61. doi:10.1002/oby.20683.

35. National Sleep Foundation. *Summary of Findings*.; 2004.

36. National Sleep Foundation. *Summary of Findings*. Washington, DC, US; 2007.

37. Haghighatdoost F, Karimi G, Esmaillzadeh A, Azadbakht L. Sleep deprivation is associated with lower diet quality indices and higher rate of general and central

obesity among young female students in Iran. *Nutrition*. 2012;28(11-12):1146–50. doi:10.1016/j.nut.2012.04.015.

38. Kim MJ, Lee JH, Duffy JF. Circadian Rhythm Sleep Disorders. *J Clin Outcomes Manag*. 2013;20(11):513–528. doi:10.1016/j.biotechadv.2011.08.021.Secreted.

39. Markwald RR, Melanson EL, Smith MR, et al. Impact of insufficient sleep on total daily energy expenditure, food intake, and weight gain. *Proc Natl Acad Sci U S A*. 2013;110(14):5695–700. doi:10.1073/pnas.1216951110.

40. Taheri S, Lin L, Austin D, Young T, Mignot E. Short sleep duration is associated with reduced leptin, elevated ghrelin, and increased body mass index. *PLoS Med*. 2004;1(3):e62. doi:10.1371/journal.pmed.0010062.

41. Patel SR, Hu FB. Short sleep duration and weight gain: a systematic review. *Obesity (Silver Spring)*. 2008;16(3):643–653. doi:10.1038/oby.2007.118.Short.

42. Kjeldsen JS, Hjorth MF, Andersen R, et al. Short sleep duration and large variability in sleep duration are independently associated with dietary risk factors for obesity in Danish school children. *Int J Obes*. 2014;38(1):32–9. doi:10.1038/ijo.2013.147.

43. Lana A, Rodríguez-Artalejo F, Lopez-Garcia E. Consumption of sugar-sweetened beverages is positively related to insulin resistance and higher plasma leptin concentrations in men and nonoverweight women. *J Nutr*. 2014;144(7):1099–105. doi:10.3945/jn.114.195230.

44. Grandner M a, Jackson N, Gerstner JR, Knutson KL. Dietary nutrients associated

with short and long sleep duration. Data from a nationally representative sample. *Appetite*. 2013;64:71–80. doi:10.1016/j.appet.2013.01.004.

45. Kant AK, Graubard BI. Association of self-reported sleep duration with eating behaviors of American adults: NHANES 2005-2010. *Am J Clin Nutr*. 2014:938–947. doi:10.3945/ajcn.114.085191.938.

46. Montgomery-Downs HE, Insana SP, Clegg-Kraynok MM, Mancini LM. Normative longitudinal maternal sleep: the first four postpartum months. *Am J Obstet Gynecol*. 2010;203(5):465. e1– 465.e7. doi:10.1016/j.ajog.2010.06.057.Normative.

47. Hunter LP, Rychnovsky JD, Yount SM. A selective review of maternal sleep characteristics in the postpartum period. *J Obstet Gynecol Neonatal Nurs*. 2009;38(1):60–8. doi:10.1111/j.1552-6909.2008.00309.x.

48. Ulman TF, Von Holle A, Torgersen L, Stoltenberg C, Reichborn-Kjennerud T, Bulik CM. Sleep Disturbances and Binge Eating Disorder Symptoms during and after Pregnancy. *Sleep*. 2012;35(10):1403–1411. doi:10.5665/sleep.2124.

49. Hagen EW, Mirer AG, Palta M, Peppard PE. The sleep-time cost of parenting: sleep duration and sleepiness among employed parents in the Wisconsin Sleep Cohort Study. *Am J Epidemiol*. 2013;177(5):394–401. doi:10.1093/aje/kws246.

50. Santiago LB, Jorge SM, Moreira AC. Longitudinal evaluation of the development of salivary cortisol circadian rhythm in infancy. *Clin Endocrinol (Oxf)*. 1996;44:157–161.

51. Horiuchi S, Nishihara K. Analyses of mothers' sleep logs in postpartum periods. *Psychiatry Clin Neurosci*. 1999;53:137–139. doi:10.1046/j.1440-1819.1999.00519.x.

52. Dørheim SK, Bondevik GT, Eberhard-Gran M, Bjorvatn B. Sleep and depression in postpartum women: a population-based study. *Sleep*. 2009;32(7):847–55.

53. Patrick H, Nicklas T a. A Review of Family and Social Determinants of Children's Eating Patterns and Diet Quality. *J Am Coll Nutr*. 2005;24(2):83–92. doi:10.1080/07315724.2005.10719448.

54. Curtin LR, Mohadjer LK, Dohrmann SM, et al. The National Health and Nutrition Examination Survey: Sample Design, 1999-2006. *Natl Cent Heal Stat Vital Heal Stat*. 2012;2(155):1–39.

55. Office of Disease Prevention and Health Promotion. Sleep Health | Healthy People 2020. *HealthyPeople.gov*. 2012.

56. Yawn BP, Pace W, Wollan PC, et al. Concordance of Edinburgh Postnatal Depression Scale (EPDS) and Patient Health Questionnaire (PHQ-9) to assess increased risk of depression among postpartum women. *J Am Board Fam Med*. 2009;22(5):483–91. doi:10.3122/jabfm.2009.05.080155.

57. MacKinnon DP, Fairchild AJ, Fritz MS. Mediation analysis. *Annu Rev Psychol*. 2007;58:593–614. doi:10.1146/annurev.psych.58.110405.085542.

58. Bel S, Michels N, De Vriendt T, et al. Association between self-reported sleep duration and dietary quality in European adolescents. *Br J Nutr*. 2013;110(5):949–

59. doi:10.1017/S0007114512006046.

59. Nagel G, Zoller D, Ruf T, Rohrmann S, Linseisen J. Long-term reproducibility of a food-frequency questionnaire and dietary changes in the European Prospective Investigation into Cancer and Nutrition (EPIC)-Heidelberg cohort. *Br J Nutr*. 2007;98:194–200. doi:10.1017/S0007114507691636.

60. Block G, Wakimoto P, Jensen C, Mandel S, Green RR. Validation of a food frequency questionnaire for Hispanics. *Prev Chronic Dis*. 2006;3(3):A77. doi:A77 [pii].

61. Kipnis V, Subar AF, Midthune D, et al. Structure of Dietary Measurement Error: Results of the OPEN Biomarker Study. *Am J Epidemiol*. 2003;158(1):14–21. doi:10.1093/aje/kwg091.

62. Lee S-Y, Hsu H-C. Stress and Health-related well-being among mothers with a low birth weight infant: The role of sleep. *Soc Sci Med*. 2012;74(7):958–965. doi:10.1016/j.socscimed.2011.12.030.Stress.

63. Xiao RS, Simas TAM, Person SD, Goldberg RJ, Waring ME. Diet Quality and History of Gestational Diabetes Mellitus Among Childbearing Women, United States, 2007-2010. *Prev Chronic Dis*. 2015;12(25):1–9.

64. Mitchell DC, Lawrence FR, Hartman TJ, Curran JM. Consumption of dry beans, peas, and lentils could improve diet quality in the US population. *J Am Diet Assoc*. 2009;109(5):909–13. doi:10.1016/j.jada.2009.02.029.

65. Ma Y, Olendzki BC, Wang J, et al. Single-Component Versus Multicomponent

Dietary Goals for the Metabolic Syndrome. *Ann Intern Med*. 2015;162:248. doi:10.7326/M14-0611.

66. Ma Y, Olendzki BC, Pagoto SL, et al. Number of 24-Hour Diet Recalls Needed to Estimate Energy Intake. *Ann Epidemiol*. 2009;19(8):553–559. doi:10.1016/j.annepidem.2009.04.010.Number.

67. Lauderdale DS, Knutson KL, Yan LL, Liu K, Rathouz PJ. Self-reported and measured sleep duration: how similar are they? *Epidemiology*. 2008;19:838–845. doi:10.1097/EDE.0b013e318187a7b0.

68. Riemann D, Berger M, Voderholzer U. Sleep and depression — results from psychobiological studies: an overview. *Biol Psychol*. 2001;57:67–103. doi:10.1016/S0301-0511(01)00090-4.

69. Park EM, Meltzer-Brody S, Stickgold R. Poor sleep maintenance and subjective sleep quality are associated with postpartum maternal depression symptom severity. *Arch Womens Ment Heal*. 2013;16(6):539–47. doi:10.1007/s00737-013-0356-9.

70. George GC, Milani TJ, Hanss-Nuss H, Freeland-Graves JH. Compliance with dietary guidelines and relationship to psychosocial factors in low-income women in late postpartum. *J Am Diet Assoc*. 2005;105(6):916–926. doi:10.1016/j.jada.2005.03.009.

71. Zipf G, Chiappa M, Porter KS, Ostchega Y, Lewis BG, Dostal J. National health and nutrition examination survey: plan and operations, 1999-2010. *Natl Cent Heal*

Stat Vital Heal Stat. 2013;1(56):1–37.

72. Bansil P, Kuklina E V, Merritt RK, Yoon PW. Associations between sleep disorders, sleep duration, quality of sleep, and hypertension: results from the National Health and Nutrition Examination Survey, 2005 to 2008. *J Clin Hypertens (Greenwich)*. 2011;13(10):739–43. doi:10.1111/j.1751-7176.2011.00500.x.

73. Vladutiu CJ, Evenson KR, Borodulin K, Deng Y, Dole N. The Association Between Physical Activity and Maternal Sleep During the Postpartum Period. *Matern Child Health J*. 2014. doi:10.1007/s10995-014-1458-3.

74. Durham HA, Morey MC, Lovelady CA, Namenek Brouwer RJ, Krause KM, Ostbye T. Postpartum physical activity in overweight and obese women. *J Phys Act Health*. 2011;8(7):988–993.

75. O'hara MW, Swain AM. Rates and risk of postpartum depression—a meta-analysis. *Int Rev Psychiatry*. 1996;8:37–54. doi:10.3109/09540269609037816.

76. Segre LS, O'Hara MW, Arndt S, Stuart S. The prevalence of postpartum depression: the relative significance of three social status indices. *Soc Psychiatry Psychiatr Epidemiol*. 2007;42:316–321. doi:10.1007/s00127-007-0168-1.

77. Ram S, Seirawan H, Kumar SKS, Clark GT. Prevalence and impact of sleep disorders and sleep habits in the United States. *Sleep Breath*. 2010;14(1):63–70. doi:10.1007/s11325-009-0281-3.

78. Grandner MA, Jackson NJ, Pak VM, Gehrman PR. Sleep disturbance is associated

with cardiovascular and metabolic disorders. *J Sleep Res*. 2012;21:427–433. doi:10.1111/j.1365-2869.2011.00990.x.

79. Yu ZM, Parker L, Dummer TJB. Depressive symptoms, diet quality, physical activity, and body composition among populations in Nova Scotia, Canada: report from the Atlantic Partnership for Tomorrow's Health. *Prev Med (Baltim)*. 2014;61:106–13. doi:10.1016/j.ypmed.2013.12.022.

80. Moore L V, Diez Roux A V, Nettleton J a, Jacobs DR. Associations of the local food environment with diet quality--a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis. *Am J Epidemiol*. 2008;167(8):917–24. doi:10.1093/aje/kwm394.

81. Fowles ER, Bryant M, Kim S, et al. Predictors of dietary quality in low-income pregnant women: a path analysis. *Nurs Res*. 2011;60(5):286–94. doi:10.1097/NNR.0b013e3182266461.

82. Bickel G, Nord M, Price C, Hamilton W, Cook J. Guide to Measuring Household Food Security, Revised 2000. *US Dep Agric Food Nutr Serv Alexandria VA*. 2000.

83. Haskell WL, Lee I-MM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;39(8):1423–34. doi:10.1249/mss.0b013e3180616b27.

84. Jensen MD, Ryan DH, Apovian CM, et al. 2013 AHA/ACC/TOS Guideline for the Management of Overweight and Obesity in Adults: A Report of the American

College of Cardiology/American Heart Association Task Force on Practice Guidelines and The Obesity Society. *Circulation*. 2014;129(25_suppl_2):S102–S138. doi:10.1161/01.cir.0000437739.71477.ee.

85. National Center for Health Statistics Center for Disease Control and Prevention. Analytic and Reporting Guidelines The National Health and Nutrition Examination Survey (NHANES). *Prevention*. 2006:1–14.

86. Kroenke K, Spitzer RL, Williams JBW. The PHQ-9 Validity of a Brief Depression Severity Measure. *J Gen Intern Med*. 2001;16(9):606–613.

87. Moriarty AS, Gilbody S, McMillan D, Manea L. Screening and case finding for major depressive disorder using the Patient Health Questionnaire (PHQ-9): a meta-analysis. *Gen Hosp Psychiatry*. 2015;37(6):567–576. doi:10.1016/j.genhosppsych.2015.06.012.

88. Hogenkamp PS, Nilsson E, Nilsson VC, et al. Acute sleep deprivation increases portion size and affects food choice in young men. *Psychoneuroendocrinology*. 2013;38(9):1668–1674. doi:10.1016/j.psyneuen.2013.01.012.

89. Lundahl a., Nelson TD. Sleep and food intake: A multisystem review of mechanisms in children and adults. *J Health Psychol*. 2015;20(6):794–805. doi:10.1177/1359105315573427.

90. Allan JL, Johnston M, Campbell N. Missed by an inch or a mile? Predicting the size of intention-behaviour gap from measures of executive control. *Psychol Health*. 2011;26(6):635–650. doi:10.1080/08870441003681307.

91. Mindell JA, Sadeh A, Kwon R, Goh DYT. Relationship Between Child and Maternal Sleep: A Developmental and Cross-Cultural Comparison. *J Pediatr Psychol*. 2015;40(7):689–96. doi:10.1093/jpepsy/jsv008.

92. Zadeh SS, Begum K. Comparison of nutrient intake by sleep status in selected adults in Mysore, India. *Nutr Res Pract*. 2011;5(3):230–235. doi:10.4162/nrp.2011.5.3.230.

93. Grandner MA, Jackson N, Gerstner JR, Knutson KL. Sleep symptoms associated with intake of specific dietary nutrients. *J Sleep Res*. 2014;23(1):22–34. doi:10.1111/jsr.12084.

94. Wang L, Wu T, Anderson JL, Florence JE. Prevalence and risk factors of maternal depression during the first three years of child rearing. *J Womens Health (Larchmt)*. 2011;20(5):711–718. doi:10.1089/jwh.2010.2232.

95. Center on the Developing Child at Harvard University. *Maternal Depression can Undermine the Development of Young children*.; 2009.

96. Murphy MJ, Peterson MJ. Sleep Disturbances in Depression. *Sleep Med Clin*. 2015;10(1):17–23. doi:10.1016/j.jsmc.2014.11.009.

97. Sivertsen B, Hysing M, Dørheim SK, Eberhard-Gran M. Trajectories of maternal sleep problems before and after childbirth: a longitudinal population-based study. *BMC Pregnancy Childbirth*. 2015;15(1):129. doi:10.1186/s12884-015-0577-1.

98. Del Brutto OH, Mera RM, Zambrano M, Del Brutto VJ, Castillo PR. Association between sleep quality and cardiovascular health: a door-to-door survey in rural

Ecuador. *Environ Health Prev Med*. 2014;19(3):234–7. doi:10.1007/s12199-014-0379-5.

99. Engeda J, Mezuk B, Ratliff S, Ning Y. Association between duration and quality of sleep and the risk of pre-diabetes: evidence from NHANES. *Diabet Med*. 2013;30(6):676–80. doi:10.1111/dme.12165.

100. Thomson C a, Morrow KL, Flatt SW, et al. Relationship between sleep quality and quantity and weight loss in women participating in a weight-loss intervention trial. *Obesity (Silver Spring)*. 2012;20(7):1419–25. doi:10.1038/oby.2012.62.

101. Liu R, Liu X, Zee PC, et al. Association between sleep quality and C-reactive protein: results from national health and nutrition examination survey, 2005-2008. *PLoS One*. 2014;9(3):e92607. doi:10.1371/journal.pone.0092607.

102. Doan T, Gardiner A, Gay CL, Lee K a. Breast-feeding increases sleep duration of new parents. *J Perinat Neonatal Nurs*. 2007;21(3):200–6. doi:10.1097/01.JPN.0000285809.36398.1b.

103. Quillin SIM. Interaction Between Feeding Method and Co-Sleeping on Maternal-Newborn Sleep. *J Obstet Gynecol Neonatal Nurs*. 2004;33(5):580–588. doi:10.1177/0884217504269013.

104. Fowles ER, Walker LO. Correlates of dietary quality and weight retention in postpartum women. *J Community Health Nurs*. 2006;23(3):187–197. doi:10.1207/s15327655jchn2303.

105. Magee L, Hale L. Longitudinal associations between sleep duration and

subsequent weight gain: a systematic review. *Sleep Med Rev*. 2012;16(3):231–41. doi:10.1016/j.smrv.2011.05.005.

106. 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(2):414–420. doi:10.2337/dc09-1124.

107. Cappuccio FP, Cooper D, Delia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: A systematic review and meta-analysis of prospective studies. *Eur Heart J*. 2011;32(12):1484–1492. doi:10.1093/eurheartj/ehr007.

108. National Center for Health Statistics, Survey NH and N. National Health and Nutrition Examination Survey 1999 – 2012 Survey Content Brochure. 2012:1–13.

109. Spiegel K, Tasali E, Penev P, Cauter E Van. Brief Communication : Sleep Curtailment in Healthy Young Men Is Associated with Decreased Leptin Levels , Elevated Ghrelin Levels , and increased hunger and appetite. *Ann Intern Med*. 2004;141:846–851.

110. Connor Gorber S, Tremblay M, Moher D, Gorber B. A comparison of direct vs. self-report measures for assessing height, weight and body mass index: a systematic review. *Obes Rev*. 2007;8(4):307–26. doi:10.1111/j.1467-789X.2007.00347.x.

111. Bull FC, Maslin TS, Armstrong T. Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *J Phys Act Health*. 2009;6:790–804.

112. Appelhans BM, Waring ME, Schneider KL, Pagoto SL. Food preparation supplies predict children’s family meal and home-prepared dinner consumption in low-income households. *Appetite*. 2014;76C(January):1–8. doi:10.1016/j.appet.2014.01.008.

113. Virudachalam S, Long J a, Harhay MO, Polsky DE, Feudtner C. Prevalence and patterns of cooking dinner at home in the USA: National Health and Nutrition Examination Survey (NHANES) 2007-2008. *Public Health Nutr*. 2014;17(5):1022–30. doi:10.1017/S1368980013002589.

114. Patel SR. Reduced sleep as an obesity risk factor. *Obes Rev*. 2009;10 Suppl 2(9):61–8. doi:10.1111/j.1467-789X.2009.00664.x.

115. Nielsen LS, Danielsen K V, Sørensen TI a. Short sleep duration as a possible cause of obesity: critical analysis of the epidemiological evidence. *Obes Rev*. 2011;12(2):78–92. doi:10.1111/j.1467-789X.2010.00724.x.