Published in final edited form as:

Headache. 2015 April ; 55(4): 550–561. doi:10.1111/head.12527.

Dietary Intake Patterns and Diet Quality in a Nationally Representative Sample of Women With and Without Severe Headache or Migraine

E. Whitney Evans, PhD, RD, Richard B. Lipton, MD, B. Lee Peterlin, MD, Hollie A. Raynor, PhD, RD, J. Graham Thomas, PhD, Kevin C. O'Leary, MS, Jelena Pavlovic, MD, Rena R. Wing, PhD, and Dale S. Bond, PhD

Weight Control and Diabetes Research Center, The Miriam Hospital, Brown University Alpert Medical School, Providence, RI, USA (E.W. Evans, J.G. Thomas, K.C. O'Leary, R.R. Wing, and D.S. Bond); Department of Neurology, Montefiore Medical Center, Albert Einstein College of Medicine, Bronx, NY, USA (R.B. Lipton and J. Pavlovic); Department of Neurology, Johns Hopkins University School of Medicine, Baltimore, MD, USA (B.L. Peterlin); Department of Nutrition, University of Tennessee, Knoxville, TN, USA (H.A. Raynor).

Abstract

Objective/Background—The role of diet in migraine is not well understood. We sought to characterize usual dietary intake patterns and diet quality in a nationally representative sample of women with and without severe headache or migraine. We also examined whether the relationship between migraine and diet differs by weight status.

© 2015 American Headache Society

Address all correspondence to E.W. Evans, Weight Control and Diabetes Research Center, 196 Richmond St, Providence, RI 02903, USA, Whitney_evans@brown.edu.

STATEMENT OF AUTHORSHIP

Category 1

(a) Conception and Design

E. Whitney Evans, Richard B. Lipton, B. Lee Peterlin, Hollie A. Raynor, J. Graham Thomas, Kevin C. O'Leary, Jelena Pavlovic, Rena R. Wing, Dale S. Bond

(b) Acquisition of Data

E. Whitney Evans

(c) Analysis and Interpretation of Data

E. Whitney Evans was primarily responsible to data analysis; E. Whitney Evans, Richard B. Lipton, B. Lee Peterlin, Hollie A. Raynor, J. Graham Thomas, Kevin C. O'Leary, Jelena Pavlovic, Rena R. Wing, Dale S. Bond contributed to interpretation of findings

Category 2

(a) Drafting the Manuscript

E. Whitney Evans wrote first draft; E. Whitney Evans, Richard B. Lipton, B. Lee Peterlin, Hollie A. Raynor, J. Graham Thomas, Kevin C. O'Leary, Jelena Pavlovic, Rena R. Wing, Dale S. Bond provided input and revision

(b) Revising It for Intellectual Content

E. Whitney Evans, Richard B. Lipton, B. Lee Peterlin, Hollie A. Raynor, J. Graham Thomas, Kevin C. O'Leary, Jelena Pavlovic, Rena R. Wing, Dale S. Bond

Category 3

(a) Final Approval of the Completed Manuscript

E. Whitney Evans, Richard B. Lipton, B. Lee Peterlin, Hollie A. Raynor, J. Graham Thomas, Kevin C. O'Leary, Jelena Pavlovic, Rena R. Wing, Dale S. Bond

Conflict of Interest: Dr. E. Whitney Evans, Dr. Richard Lipton, Dr. Hollie Raynor, Dr. J. Graham Thomas, Kevin C. O'Leary, Dr. Rena Wing, and Dr. Dale S. Bond have no conflicts of interest to report. Dr. B. Lee Peterlin is an associate editor at *Headache* and has received funding from Luitpold Pharmaceuticals and from the Landenberger foundation, though neither relate to this work. Dr. Jelena Pavlovic consults for Allergan, but this work is unrelated to this study.

Methods—In this analysis, women with migraine or severe headache status was determined by questionnaire for 3069 women, ages 20-50 years, who participated in the National Health and Nutrition Examination Study, 1999-2004. Women who experienced severe headaches or migraines were classified as migraine for the purposes of this analysis. Dietary intake patterns (micro- and macronutrient intake and eating frequency) and diet quality, measured by the Healthy Eating Index, 2005, were determined using one 24-hour dietary recall.

Results—Dietary intake patterns did not significantly differ between women with and without migraine. Normal weight women with migraine had significantly lower diet quality (Healthy Eating Index, 2005 total scores) than women without migraine (52.5 ± 0.9 vs 45.9 ± 1.0 ; $P < .0001$).

Conclusions—Whereas findings suggest no differences in dietary intake patterns among women with and without migraine, dietary quality differs by migraine status in normal weight women. Prospective analyses are needed to establish how diet relates to migraine onset, characteristics, and clinical features in individuals of varying weight status.

Keywords

migraine; dietary intake pattern; diet quality; overweight and obese; women

Migraine, a neurovascular disorder characterized by recurrent attacks of debilitating pain associated with photophobia, phonophobia, nausea, vomiting, and sensitivity to movement, is a significant public health problem in the United States. Migraine is highly prevalent, affecting 17% of women and 6% of men,¹ and the socioeconomic burden is substantial. Migraine causes 112 million bedridden days per year, creating considerable disruption to employment and family life.^{2,3} Moreover, costs of migraine-related disability and treatment in the United States exceed \$24 billion annually.^{2,4}

Migraine is comorbid with obesity and other chronic diseases, and this risk may be strongest in women of reproductive age.⁵⁻⁹ Although mechanisms underlying the migraine–obesity link are not well understood, one plausible mechanism is shared inflammatory processes. It is hypothesized that obesity, a low-grade chronic inflammatory state, may exacerbate the neurovascular inflammatory response in migraine.¹⁰⁻¹² Migraine and obesity may also be linked through common behavioral risk factors that promote further inflammation, one being poor dietary habits.^{12,13} Our group recently showed that obese women with migraine spent nearly 1.5 hours per day less in objectively measured physical activity compared to obese women without migraine.¹⁴ However, whether usual dietary intake patterns differ between women with and without migraine, and if the relationship between diet and migraine is affected by weight status, is not known.

Physicians have long debated the role of diet in migraine.^{15,16} Given inflammatory processes underlying migraine, both metabolic abnormalities and food allergies have been implicated in migraine onset. Commonly cited dietary triggers include chocolate, cheese, processed meats, and red wine;¹⁷ however, to date, there are no studies which unequivocally support the role of specific foods in migraine. Yet, elimination diets are often clinically recommended to mitigate migraine attacks.^{17,18} Other investigations suggest that eating

frequency, meal timing, and the macronutrient composition of the diet may also play a role in migraine.¹⁹⁻²¹ Specifically, a study in over 1000 adults with migraine found that fasting was associated with migraine onset in 57% of patients.²² Further, results of a prospective cohort trial that evaluated the effects of a low-fat dietary intervention on migraine showed an association between higher fat consumption and higher headache frequency at baseline, and significant decreases in headache frequency, intensity, duration, and medication use following significant decreases in fat consumption at post-intervention.²³ These findings suggest that a more detailed and comprehensive examination of dietary intake patterns in persons with and without migraine is warranted to better elucidate the relationship of diet and migraine.

The purpose of the current study was twofold. First, we sought to characterize typical dietary intake patterns, including micro- and macronutrient composition, eating frequency, and dietary quality, of women with and without migraine who participated in the National Health and Nutrition Examination Survey (NHANES). Given previous studies conducted in smaller clinic-based samples showing associations of migraine with irregular eating frequency and high-fat diet,^{20,21,23} we hypothesized that women with migraine would eat less frequently, consume a higher fat diet, and have poorer overall dietary quality as compared to those without migraine. Second, we examined whether the relationship between migraine and dietary intake patterns differed by weight status. In light of the association between obesity and migraine risk, and the fact that diet is an independent risk factor for obesity,²⁴ we anticipated that weight status would confound the relationship between diet and migraine. However, given the role of diet in inflammation and migraine-related and obesity-related comorbidities including elevated blood pressure and blood cholesterol levels, we also hypothesized that weight status would modify the relationship between diet and migraine.^{6,7,13} For example, in an obese woman who already has a significant level of inflammation, eating a pro-inflammatory diet low in omega-3 fatty acids and high in omega-6 fatty acids may differentially relate to migraine status as compared to in a normal weight woman.^{25,26}

METHODS

Study Design and Participants

NHANES, collected by the National Center for Health Statistics (NCHS), is a continuous program of cross-sectional surveys designed to assess the health and nutritional status of Americans. Through a health interview and Mobile Examination Center (MEC) physical exam, NHANES provides information on demographics, physiological measurements, and diet for approximately 5000 persons each cycle.²⁷ For purposes of this analysis, data from three continuous NHANES cycles (1999-2000, 2001-2002, and 2003-2004) were combined. The sample for these analyses included non-pregnant women, ages 20-50 years, who completed the NHANES pain questionnaire and provided a reliable, in-person 24-hour diet recall. We limited our sample to this age range given that migraine prevalence is highest among adult women of reproductive age.²⁸ The NHANES protocol was approved by the NCHS Institutional Review Board.²⁹

Migraine Assessment

Migraine status was assessed via self-report in the NHANES pain questionnaire, which was administered to all participants ages 20 and older in the 1999-2000, 2001-2002, and 2003-2004 surveys. Participants were asked, "During the past three months, did you have severe headaches or migraines?" Women who answered "yes" to this question were categorized as having migraine. The wording of and response options for this question require any analysis to include those reporting severe headache as having migraine. Findings from the American Migraine Prevalence and Prevention study support the inclusion of those with severe headache as having migraine. Specifically, data suggest that 17% of respondents reported having severe headache, nearly 12% of whom met the International Classification of Headache Disorders-II (ICHD-II) criteria for migraine, 5% of whom met criteria for "probable migraine," and 1% of whom were categorized as having "other severe headache."³⁰

Dietary Assessment

Dietary intake patterns were determined from one in-person 24-hour diet recall. In 1999-2000 and 2001-2002, 24-hour diet recalls were collected using the computer-assisted dietary interview (CADI) system, whereas in 2003-2004, NCHS used the United States Department of Agriculture's (USDA) Automated Multiple Pass Method (AMPM) to collect each 24-hour recall.³¹ Given that one recall can be used to adequately describe group means and that only one recall was collected until 2001, only one recall was used in this analysis.³²

Dietary Intake Patterns

To characterize the dietary intake patterns of women with and without migraine, we examined total energy intake (kcal), percent energy from each macronutrient (fat, protein, and carbohydrate), sodium intake (mg), alcohol intake (g), caffeine intake (mg), omega-3 intake (g), and the ratio of omega-6 to omega-3 fatty acids. These variables were determined for each 24-hour diet recall using the NHANES Total Nutrients File. We also examined eating frequency, defined as the number of eating occasions reported over the 24-hour recall period, as a dietary intake pattern. Both the CADI and the AMPM use probes to collect detailed information on each food and beverage consumed as well as the name and timing of each eating occasion. For purposes of these analyses, an eating occasion was defined as any distinct time when a participant reported consuming at least one food or beverage item, *excluding water*.

Diet Quality

We assessed diet quality using the Healthy Eating Index, 2005 (HEI-2005). The HEI-2005 is a scoring system designed to assess adherence to the Dietary Guidelines for Americans (DGA), 2005.³³ The HEI-2005 comprises 12 nutrient-based and food-based component scores, which reflect whether intake of food groups and nutrients meet the standards set by the 2005 DGA. Nine of the components (fruit, whole fruit, total vegetables, dark green and orange vegetables, total grains, whole grains, milk, meat and beans, and oils) represent adequacy components for which a higher score indicates higher consumption, whereas the saturated fat, sodium, and energy from solid fat, alcohol, and added sugars (SoFAAS)

represent moderation components where a higher score reflects lower consumption. With the exception of energy from SoFAAS, the HEI-2005 uses a density approach (per 1000 calories) to reflect the 2005 DGA recommendation to meet food group and nutrient needs while maintaining energy balance.³³ Total and component HEI-2005 scores were determined for each participant using the MyPyramid Equivalents Database,³⁴ the 2003-2004 addendum,³⁵ and SAS code made publically available by the USDA.³⁶

Potential Covariates

Potential demographic covariates including age, race/ethnicity, education, and marital status, were assessed via self-report during the in-person interview. Age was self-reported in years. Racial and ethnic categories were self-reported and include non-Hispanic white, non-Hispanic black, Mexican American, other race, and other Hispanic. Education level was self-reported and categorized as less than high school, completed high school, or more than high school. Marital status was self-reported and categorized as married, widowed, divorced, or separated, never married, or living with partner.

Health-related covariates included weight status, smoking status, and diabetes diagnosis. Height (in centimeters) and weight (in kilograms) were measured for each eligible participant during the MEC exam.³⁷ Body mass index (BMI: kg/m²) was calculated for each participant using height and weight measurements. Participants were classified as underweight if their BMI was less than 18.5 kg/m², normal weight if their BMI was between 18.5 and 24.9 kg/m², over-weight if their BMI was between 25.0 and 29.9 kg/m², and obese if their BMI was between 30.0 and 50.0 kg/m². Smoking status was determined via self-report questionnaire. Current smokers were defined as those who had smoked 100 cigarettes during their lifetime and were currently smoking. Former smokers were those who had smoked 100 cigarettes during their lifetime but were no longer smoking; and never smokers were those who had smoked <100 cigarettes during their lifetime. Diabetes diagnosis was also self-reported via a single question that asked, "Other than during pregnancy, have you ever been told by a doctor or health professional that you have diabetes?" Anyone who answered "yes" was considered to have diabetes. Those who reported "no" or "borderline" were considered to be diabetes free. Serum blood glucose levels (mg/dL) were measured as part of the Standard Biochemistry Profile at the time of the MEC exam.

Statistical Analysis

All descriptive and inferential statistics were obtained using Proc Survey applications in SAS (Version 9.3, 2011, SAS Institute, Cary, NC, USA) to account for the complex, multistage, probability sampling methodology used to collect NHANES data. Sample weights, which account for survey nonresponse, over-sampling, post-stratification, and sampling error for each 2-year survey, were rescaled to represent the population at the midpoint of the combined 6-year survey period.²⁷ The distribution of each dietary intake pattern variable was examined prior to analyses. Total energy intake, sodium, alcohol, and caffeine were all positively skewed. Total energy intake, sodium, and caffeine were log transformed to normalize the distribution. Geometric means are reported for these dietary intake patterns. Alcohol intake was not normally distributed, as more than 80% of participants reported no alcohol use. A transformation could not be found to normalize the

distribution, so usual alcohol intake was categorized into three groups: nonconsumers (reported alcohol intake of 0 g/day), low consumers (reported alcohol intake >0 and <14 g/day) and high consumers (reported alcohol intake >14 g/day). This categorization is consistent with the Centers for Disease Control and Prevention recommendation that women should consume no more than one alcoholic beverage per day (14 g of alcohol/day), which the amount of alcohol found in 12 ounces of beer, 8 ounces of malt liquor, 5 ounces of wine, 1.5 ounces of 80-proof distilled spirits or liquor (eg, gin, rum, vodka, whiskey).³⁸

Prior to examining the relationships of each dietary intake pattern with migraine status, we assessed the need to control for underreporting using the Goldberg Criteria.³⁹ Specifically, basal metabolic rate (BMR) was determined for each participant using the Harris-Benedict equation for women, which factors in weight (kg), height (cm), and age (years).^{40,41} BMR estimates for each participant were compared to reported total energy intake, the ratio of which yielded individual physical activity levels (PAL). Per the Goldberg Criteria, mean PAL estimates were compared for women with and without migraine against the recommended cutoff of 1.35.³⁹

The relationships of each dietary intake pattern and diet quality with migraine status were estimated using multiple linear regression models in Proc SurveyReg. Given the need to categorize alcohol consumption, its relationship with migraine status was estimated using a polytomous logistic regression model via Proc SurveyLogistic. Univariate models were initially estimated, and means/frequencies by migraine status were determined. Per *a priori* hypotheses, we tested for the presence of effect modification by weight status using an interaction term in each respective model. Where effect modification by weight status was present, separate models were fit for under-weight, normal weight, overweight, and obese women. All multivariate models controlled for age in years, race/ethnicity, and socioeconomic status (education) given the established relationships between each covariate with diet and migraine, independently. We also tested for the need to control for weight status (where it was not a significant effect modifier), marital status, smoking status, and diabetes diagnosis. Variables were retained in the model if their inclusion induced a change in the point estimate greater than 10%.⁴² Finally, where the relationship of diet quality and migraine status was statistically significant, the relationships between eating frequency and HEI-2005 component scores were examined. All tests were performed at the two-sided .05 level of significance. Where appropriate, we accounted for multiple comparisons using a Bonferroni adjustment.⁴³

RESULTS

A total of 3069 nonpregnant women, ages 20-50 years, with complete pain questionnaires and a reliable, in-person 24-hour dietary recall were included in our analyses. The overall prevalence of “severe headache or migraine in the past three months” was 33.6% ($n = 1052$). Table 1 characterizes women with and without migraine with respect to demographics and health measures associated with migraine. There were no statistically significant differences with respect to age between groups. Women without migraine were more likely to be non-Hispanic white, have more than a high school education, and married, whereas women with

migraine were more likely to be current smokers, have diabetes, and higher serum blood glucose and to be obese.

Table 2 characterizes the dietary intake patterns of women with and without migraine. Given that mean PALs for women with and without migraine were not less than the Goldberg Criteria cutoff of 1.35 ($P = .99$ for women with migraine; $P = .96$ for women without migraine) and were not statistically significantly different from each other, the full sample was used in all dietary analyses. Accounting for the fact that we examined 10 different dietary intake patterns, statistically significant differences were identified as those with a P value less than the Bonferroni adjusted value of .005. Accordingly, only reported alcohol intake was statistically significant different between women with and without migraine. Specifically, women with migraine had 1.5 times the odds of being an alcohol consumer as compared to women without migraine (odds ratio [OR]: 1.5; 95% confidence interval [CI]: 1.3 to 1.8; $P < .0001$). As detailed in the methods, we tested for effect modification by weight status for each individual dietary intake pattern. The interaction terms were not statistically significant for any of the dietary intake patterns, as tested in separate models, and the magnitude of the effect estimates did not significantly vary in multiple linear regression models (data not shown).

We also examined the relationship between diet quality, as measured by the HEI-2005, and migraine status and found a statistically significant difference between women with and without migraine ($P < .0001$). However, because we also found statistically significant effect modification by weight status, Table 3 details mean total HEI-2005 scores for women with and without migraine by weight status groups. Specifically, normal weight women without migraine reported a higher quality diet than normal weight with migraine (52.5 ± 0.9 vs 45.9 ± 1.0 ; $P < .0001$). Diet quality did not statistically significantly differ between women with and without migraine in the other BMI categories (underweight, overweight, or obese women).

Given that the difference in overall diet quality was statistically significant for normal weight women, we also examined the relationship between migraine status and each of the HEI-2005 component scores in this group. Accounting for the fact that we examined differences among the 12 component scores, statistical significance was identified for P values $< .004$. As shown in Table 4, normal weight women without migraine reported diets that more closely align with the recommendations in the 2005 DGA for intake of total fruit, dark green and orange vegetables and legumes, and percent of energy from solid fats, alcohol, and added sugar (SoFAAS) as compared with normal weight women with migraine. While not statistically significant, normal weight women without migraine also reported diets higher in whole fruit, total and whole grains, and oil and lower in sodium as compared with normal weight women with migraine.

DISCUSSION

This study includes a thorough analysis of dietary intake patterns in a nationally representative sample of women with and without severe headache or migraine. Contrary to our hypothesis, findings suggest that dietary intake patterns, including reported total energy

intake, percent of energy from macronutrients, sodium, caffeine, omega-3 fatty acids, and omega-6 to omega-3 fatty acid ratio, and eating frequency, do not significantly differ between women with and without migraine. Using the USDA's measure of diet quality (HEI-2005), our study demonstrated that among normal weight women, those with migraine had reduced dietary quality compared to those without.

While most women in the sample reported no alcohol consumption, women with migraine were significantly more likely to be alcohol consumers. This finding is surprising, given that alcohol, particularly red wine and dark liquor, is an often identified trigger for migraine. Considering women with migraine are often advised not to drink, we anticipated that this advice would mitigate any association of alcohol consumption with migraine status.¹⁷ Additional studies are needed to elucidate the role of alcohol type and total alcohol intake on migraine onset, duration of illness, and severity.

Although usual dietary intake patterns were generally not different between women with and without migraine, future research is needed to examine whether the pathophysiology of migraine may render women with this disorder more susceptible to specific dietary intake patterns. Of interest is that women with migraine reported consuming 2655.5 ± 65.4 mg of sodium per day, which is more than twice the daily recommended intake for sodium (1500 mg/day). Sodium intake affects hydration status and blood pressure, such that an intake of this amount may be related to migraine onset in the presence of other predisposing physiologic characteristics in women with migraine.⁴⁴ This finding may help to inform future research on the pathophysiology of migraine as salt appetite is promoted by orexin, a neuropeptide that is expressed in the lateral hypothalamus and is thought to play a role in migraine via participation in neurogenic inflammatory, vasodilation, and pain perception processes.^{10-12,45} Further, women with migraine reported an omega-6 to omega-3 fatty acid ratio of 11.4, which suggests that they consume 11 times more pro-inflammatory omega-6 fatty acids as compared to the anti-inflammatory omega-3 fatty acids. Again, while not practically or statistically significantly different from women without migraine (11.3 ± 0.2), excess intake of omega-6 fatty acids in the context of very low omega-3 fatty acid intake may promote inflammation in women who are predisposed to migraine differentially as compared to those without migraine.⁴⁶ This is supported by a recent randomized controlled trial that showed increasing omega-3 intake while reducing omega-6 intake reduces headache severity and length in chronic headache patients.⁴⁷ More research is needed to understand the roles of sodium intake and the omega-6 to omega-3 fatty acid ratio in migraine onset and severity.

Despite the strong association between obesity and migraine, we did not find that obesity modified the relationship between dietary intake patterns and migraine status as anticipated. As aforementioned, diet is a risk factor for obesity, which through shared inflammatory and other physiological pathways is independently associated with migraine. It is therefore possible that women with worse dietary intake patterns are at higher risk for obesity, and in turn, migraine. Moreover, it is also possible that obese women, independent of migraine status, have less variability in their dietary intake patterns and dietary quality. Given the cross-sectional study design, we cannot address whether obesity is a mediator in the

relationship between diet and migraine. Therefore, longitudinal analyses examining the relationship between diet, obesity, and migraine are warranted.

Our analyses support that dietary quality differs between normal weight women with and without migraine. This difference is attributable to the fact that normal weight women without migraine report diets that more closely align with DGA, 2005 recommended intakes for total fruit, dark green and orange vegetables and legumes, and energy from SoFAAS. Interestingly, women in all weight status groups, with and without migraine, reported a low-quality diet.⁴⁸ Whereas the difference in diet quality between obese women with and without migraine was not statistically significant, obese women with migraine reported consuming a lower quality diet than those without migraine (46.6 ± 0.09 vs 48.8 ± 0.7 ; $P = .09$). Additional research using valid migraine diagnostic measures is needed to determine if dietary quality in obese women is associated with migraine characteristics including frequency, intensity, and duration.

This study has several strengths. To our knowledge, this is the first study to examine the relationships between dietary intake patterns and migraine status, along with the influence of weight status, in a nationally representative sample. Finally, another strength provided by the use of NHANES data is the detailed dietary information provided by the 24-hour diet recall collected using the USDA's validated CADI and AMPM. Both methods review the diet multiple times using questions and memory aids.⁴⁹ Whereas use of a single dietary recall may be viewed as a limitation, we examined dietary intake patterns and dietary quality at the group level. Therefore, the use of a single 24-hour diet recall is appropriate.³²

This study is not without limitations. First, the data are cross-sectional in nature. While we can make no conclusions with respect to causality, this analysis does provide valuable insight into the typical dietary intake patterns of women with migraine. Second, migraine status was determined based on self-report of migraine and severe headache. It is likely that some participants do not meet the ICHD-II criteria for migraine; however, the frequencies observed in this nationally representative sample are similar to those reported elsewhere.^{1,30,50} Finally, the data used for these analyses are from 1999 to 2004. Whereas these data are not from the most recent cycles of NHANES, migraine status was not assessed after 2003-2004; therefore, these are the only nationally representative data available in which both migraine status and diet were concurrently examined.

This study showed that dietary intake patterns in women with migraine are not substantially different from those of women without migraine. Whereas weight status does not appear to modify the relationship between diet and migraine status, differences were found for dietary quality. Normal weight women with migraine consume, on average, lower quality diets than women without migraine. Given the poor dietary quality of women with migraine, these findings suggest that addressing diet during migraine treatment may improve the overall health of women with migraine. Future studies should prospectively examine how dietary intake patterns and dietary quality relate to migraine onset, characteristics, and clinical features in individuals of varying weight status.

Acknowledgments

This work was funded, in part, by R01 NS077925 (DSB) by T32 HL076134 (EWE), and by K23 NS078345 (BLP).

Abbreviations

AMPM	automated multiple pass method
BMI	body mass index (kg/m ²)
BMR	basal metabolic rate
CADI	Computer-Assisted Dietary Interview
DGA	Dietary Guidelines for Americans
HEI-2005	Healthy Eating Index, 2005
ICHD-II	International Classification of Headache Disorders-II
MEC	Mobile Examination Center
NCHS	National Center for Health Statistics
NHANES	National Health and Nutrition Examination Survey
PAL	physical activity levels
SoFAAS	Solid fat, alcohol, and added sugars
USDA	United States Department of Agriculture

REFERENCES

1. Stewart W, Roy J, Lipton R. Migraine prevalence, socioeconomic status, and social causation. *Neurology*. 2013; 81:948–955. [PubMed: 23990405]
2. Hu X, Markson L, Lipton R, Stewart W, Berger M. Burden of migraine in the United States: Disability and economic costs. *Arch Intern Med*. 1999; 159:813–818. [PubMed: 10219926]
3. Jensen R, Stovner LJ. Epidemiology and comorbidity of headache. *Lancet Neurol*. 2008; 7:354–361. [PubMed: 18339350]
4. Hawkins K, Wang S, Rupnow M. Direct cost burden among insured US employees with migraine. *Headache*. 2008; 48:553–563. [PubMed: 18070057]
5. Peterlin B, Rosso A, Rapoport A, Scher A. Obesity and migraine: The effect of age, gender and adipose tissue distribution. *Headache*. 2009; 50:52–60. [PubMed: 19496830]
6. Bigal M, Kurth T, Santanello N, et al. Migraine and cardiovascular disease: A population-based study. *Neurology*. 2010; 74:628–635. [PubMed: 20147658]
7. Mancia G, Rosei EA, Ambrosioni E, et al. Hyper-tension and migraine comorbidity: Prevalence and risk of cerebrovascular events: Evidence from a large, multicenter, cross-sectional survey in Italy (MIRACLES study). *J Hypertens*. 2011; 29:309–318. 310.1097/HJH.1090b1013e3283410404. [PubMed: 21119534]
8. Winsvold BS, Hagen K, Aamodt AH, Stovner LJ, Holmen J, Zwart JA. Headache, migraine and cardiovascular risk factors: The HUNT study. *Eur J Neurol*. 2011; 18:504–511. [PubMed: 20825470]
9. Peterlin B, Rosso A, Williams M, et al. Episodic migraine and obesity and the influence of age, race and sex. *Neurology*. 2013; 81:1314–1321. [PubMed: 24027060]
10. Chai C, Scher A, Moghekar A, Bond D, Peterlin B. Obesity and headache: Part II – Potential mechanisms and treatment considerations. *Headache*. 2014; 54:459–471. [PubMed: 24511882]

11. Bigal M, Lipton R, Holland P, Goadsby P. Obesity, migraine, and chronic migraine: Possible mechanisms of interaction. *Neurology*. 2007; 68:1851–1861. [PubMed: 17515549]
12. Peterlin B, Rapoport A, Kurth T. Migraine and obesity: Epidemiology, mechanisms, and implications. *Headache*. 2009; 50:631–648. [PubMed: 19845784]
13. Bond D, Roth J, Nash J, Wing R. Migraine and obesity: Epidemiology, possible mechanisms and the potential role of weight loss treatment. *Obes Rev*. 2011; 12:e362–e371. [PubMed: 20673279]
14. Bond, D.; Thomas, J.; O'Leary, K., et al. Objectively-measured physical activity in obese women with and without migraine. *Cephalalgia*; 2014. doi: 10.1177/0333102414562970
15. Symonds C. Discussion on migraine. *Proc R Soc Med*. 1927; 20:1097–1110. [PubMed: 19985848]
16. Peterlin B. Bariatric surgery in obese migraineurs: Mounting evidence but important questions remain. *Cephalalgia*. 2011; 31:1333–1335. [PubMed: 21914731]
17. Finocchi C, Sivori G. Food as trigger and aggravating factor of migraine. *Neurol Sci*. 2012; 33:77–80.
18. Finkel A, Yerry J, Mann J. Dietary consideration in migraine management: Does a consistent diet improve migraine. *Curr Pain Headache Rep*. 2013; 17:373–381. [PubMed: 24068338]
19. Turner DP, Smitherman TA, Penzien DB, Porter JAH, Martin VT, Houle TT. Nighttime snacking, stress, and migraine activity. *J Clin Neurosci*. 2014; 21:638–643. [PubMed: 24417796]
20. Molarius A, Tegelberg A, Ohrvik J. Socioeconomic factors, lifestyle, and headache disorders – A population-based study in Sweden. *Headache*. 2008; 48:1426–1437. [PubMed: 18624712]
21. Nazari F, Safavi M, Mahmudi M. Migraine and its relation with lifestyle in women. *Pain Pract*. 2010; 10:228–234. [PubMed: 20158623]
22. Kelman L. The triggers or precipitants of the acute migraine attack. *Cephalalgia*. 2007; 27:394–402. [PubMed: 17403039]
23. Bic A, Blix G, Hopp H, Leslie F, Schell M. The influence of a low-fat diet on incidence and severity of migraine headaches. *J Womens Health Gend Based Med*. 1999; 8:623–630. [PubMed: 10839648]
24. Swinburn B, Caterson I, Seidell J, James W. Diet, nutrition and the prevention of excess weight gain and obesity. *Public Health Nutr*. 2004; 7(1a):123–146. [PubMed: 14972057]
25. Simopoulos AP. The importance of the ratio of omega-6/omega-3 essential fatty acids. *Biomed Pharmacother*. 2002; 56:365–379. [PubMed: 12442909]
26. Simopoulos AP. The importance of the omega-6/omega-3 fatty acid ratio in cardiovascular disease and other chronic diseases. *Exp Biol Med*. 2008; 233:674–688.
27. Center for Disease Control and Prevention. Continuous NHANES web tutorial. 2009. http://www.cdc.gov/nchs/tutorials/Nhanes/index_continuous.htm
28. Lipton R, Bigal M, Diamond M, Freitag F, Reed M, Stewart W. Migraine prevalence, disease burden, and the need for preventive therapy. *Neurology*. 2007; 68:343–349. [PubMed: 17261680]
29. National Center for Health Statistics. NCHS Research Ethics Review Board Approval. 2014. <http://www.cdc.gov/nchs/nhanes/irba98.htm>
30. Buse D, Loder E, Gorman J, et al. Sex differences in the prevalence, symptoms, and associated features of migraine, probable migraine and other severe head ache: Results of the American migraine prevalence and prevention (AMPP) study. *Headache*. 2013; 53:1278–1299. [PubMed: 23808666]
31. National Center for Health Statistics. Key concepts about NHANES dietary data collection. NHANES Dietary Web Tutorial. 2010. <http://www.cdc.gov/nchs/tutorials/dietary/SurveyOrientation/DietaryDataOverview/Info2.htm>
32. Willett, W. *Nutritional Epidemiology*. 2nd edn.. Oxford University Press; New York: 1998.
33. Guenther P, Reedy J, Krebs-Smith S. Development of the Healthy Eating Index-2005. *J Am Diet Assoc*. 2008; 108:1896–1901. [PubMed: 18954580]
34. Beltsville Human Nutrition Research Center. Agricultural Research Service, USDA. MyPyramid equivalents database, 2.0 for USDA Survey Foods, 2003-2004. 2003-2004. <http://www.ars.usda.gov/services/docs.htm?docid=17558>.
35. Koegel, K.; Kuczynski, K. Addendum to the MyPyramid equivalents database 2.0. 2011. <http://www.cnpp.usda.gov/OtherProjects.htm>

36. United States Department of Agriculture. Healthy Eating Index-2005 development and evaluation technical report support files. 2010. <http://www.cnpp.usda.gov/HealthyEatingIndex-2005report.htm>
37. National Center for Health Statistics. Anthropometry and physical activity monitor procedures manual. 2005. http://www.cdc.gov/nchs/data/nhanes/nhanes_05_06/BM.pdf
38. Center for Disease Control and Prevention. Public health and alcohol. 2014. <http://www.cdc.gov/alcohol/faqs.htm>.
39. Goldberg G, Black A. Assessment of the validity of reported energy intakes – Review and recent developments. *Scand J Nutr.* 1998; 42:6–9.
40. Kien CL, Ugrasbul F. Prediction of daily energy expenditure during a feeding trial using measurements of resting energy expenditure, fat-free mass, or Harris-Benedict equations. *Am J Clin Nutr.* 2004; 80:876–880. [PubMed: 15447893]
41. Harris J, Benedict F. A biometric study of human basal metabolism. *P Natl Acad Sci U S A.* 1918; 4:370–373.
42. Rothman, K.; Greenland, S.; Lash, T. *Modern Epidemiology.* 3rd edn.. Lippincott Williams & Wilkins; Philadelphia: 2008.
43. Bendera R, Langeb S. Adjusting for multiple testing-when and how? *J Clin Epidemiol.* 2001; 54:343–349. [PubMed: 11297884]
44. Institute of Medicine. *Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate.* Institute of Medicine; Washington, DC: 2004.
45. Hurley S, Johnson A. The role of the lateral hypothalamus and orexin in ingestive behavior: A model for the translation of past experience and sensed deficits into motivated behaviors. *Front Syst Neurosci.* 2014; 8:216. doi: 10.3389/fnsys.2014.00216. [PubMed: 25431553]
46. Simopoulos A. The importance of the ratio of omega-6/omega-3 essential fatty acids. *Biomed Pharmacother.* 2002; 56:365–379. [PubMed: 12442909]
47. Ramsden CE, Faurot KR, Zamora D, et al. Targeted alteration of dietary n-3 and n-6 fatty acids for the treatment of chronic headaches: A randomized trial. *Pain.* 2013; 154:2441–2451. [PubMed: 23886520]
48. Ervin, R. Healthy Eating Index-2005 total and component scores for adults aged 20 and over: National Health and Nutrition Examination Survey, 2003-2004. National Center for Health Statistics; Hyattsville, MD: 2011.
49. Raper N, Perloff B, Ingwersen I, Steinfeldt L, Anand J. An overview of USDA's dietary intake data system. *J Food Compos Anal.* 2004; 17:545–555.
50. Headache Classification Committee of the International Headache Society. International classification of headache disorders. 3rd edition.. Vol. 33. *Cephalalgia*; 2013. p. 629-808.

Table 1

Demographic Characteristics and Health Measures of Women, Ages 18 to 50 Years, With and Without Migraine Who Participated in the NHANES, 1999-2004

	Women With Migraine (<i>n</i> = 1041)	Women Without Migraine (<i>n</i> = 1982)	<i>P</i> Value [†]
Age (mean years ± SE)	35.5 ± 0.4	35.6 ± 0.3	.68
Race/ethnicity (% ± SE)			
Non-Hispanic white	64.5 ± 3.1	69.4 ± 1.8	.008
Non-Hispanic black	13.8 ± 1.5	12.6 ± 1.2	
Mexican American	8.7 ± 1.2	8.1 ± 1.0	
Other race	3.9 ± 0.9	3.7 ± 0.5	
Other Hispanic	9.1 ± 2.2	6.2 ± 1.2	
Education level (% ± SE)			
Less than a high school education	19.8 ± 1.4	14.6 ± 1.0	<.0001
High school education	25.6 ± 1.8	24.2 ± 1.4	
More than a high school education	54.6 ± 2.1	61.2 ± 1.8	
Marital status (% ± SE)			
Married	50.9 ± 1.8	56.3 ± 1.5	<.0001
Widowed	1.7 ± 0.5	1.4 ± 0.3	
Divorced or separated	18.1 ± 1.7	12.4 ± 1.0	
Never married	19.8 ± 1.7	24.2 ± 1.5	
Living with partner	9.4 ± 1.2	6.7 ± 0.6	
Smoking status (% ± SE)			
Current (currently smoking)	30.9 ± 1.7	24.6 ± 1.3	<.0001
Former (not smoking currently)	14.2 ± 1.6	16.4 ± 1.0	
Never (<100 cigarettes in lifetime)	54.9 ± 1.8	58.9 ± 1.6	
Diabetes (yes/no, self-report) (% ± SE)	3.8 ± 0.5	2.5 ± 0.4	<.0001
Serum glucose (mg/dL) (mean ± SE)	89.2 ± 1.0	87.8 ± 0.4	.02
Weight status (% ± SE)			
Normal (18.5 BMI 24.9 kg/m ²)	34.1 ± 1.9	44.1 ± 1.7	<.0001
Overweight (25.0 BMI 29.9 kg/m ²)	26.9 ± 1.9	26.5 ± 1.4	
Obese (30.0 BMI 50.0 kg/m ²)	39.0 ± 1.5	29.4 ± 1.4	

BMI = body mass index; NHANES = National Health and Nutrition Examination Survey; SE = standard error.

[†]P value based on Rao-Scott chi-square test as determined using Proc SurveyFreq or Student's *t*-test as determined by Proc SurveyReg, both of which account for NHANES complex multisampling design.

Table 2

Dietary Intake Patterns in Women, Ages 20 to 50 Years, With and Without Migraine Who Provided a Reliable, In-Person 24-Hour Diet Recall in the National Health and Nutrition Examination Survey, 1999-2004[†]

	Women With Migraine (n = 1036)	Women Without Migraine (n = 1959)	
Dietary Intake Pattern	Mean ± SE		P value ^{‡,§}
Total daily energy intake (kcal) [¶]	1800 ± 33.0	1808 ± 20.0	.80
Percent energy from fat	32.6 ± 0.5	33.6 ± 0.3	.08
Percent energy from protein	14.5 ± 0.3	15.0 ± 0.2	.11
Percent calories from carbohydrate	52.2 ± 0.6	50.6 ± 0.4	.02
Sodium intake (mg) [¶]	2655.5 ± 65.4	2744.6 ± 53.0	.30
Caffeine intake (mg) [¶]	106.5 ± 9.0	94.1 ± 6.6	.24
Omega-3 (mg) [¶]	1.0 ± 0.04	1.1 ± 0.03	.11
Omega-6: Omega-3	11.4 ± 0.2	11.3 ± 0.2	.70
Eating frequency (number of eating occasions/day)	4.9 ± 0.09	5.0 ± 0.06	.20
	OR	95% CI	P value
Alcohol intake (consumers vs non-consumers)	1.5	1.3 to 1.8	<.0001

Back transformed geometric means are reported.

CI = confidence interval; OR = odds ratio; SE = standard error.

[†] Dietary variables represent group means from one in-person 24-hour recall.

[‡] As determined by Proc SurveyReg using weights appropriate for those who provided one in-person 24-hour recall.

[§] To account for multiple comparisons, a Bonferroni adjustment was done. Significance was identified as $P < .005$.

[¶] Reported total energy, sodium, caffeine, and omega-3 intake were not normally distributed and required a log-transformation.

Table 3

Differences in Diet Quality, as Measured by the Healthy Eating Index, 2005, by Weight Status Group in Women, Ages 20 to 50 Years, With and Without Migraine, Who Provided a Reliable, in-Person 24-Hour Diet Recall in the National Health and Nutrition Examination Survey, 1999-2004^{†‡}

Weight Status	BMI Definition (kg/m ²)	Women With Migraine	Women Without Migraine	P value
		Mean ± SE		
Underweight	BMI < 18.5	45.1 ± 2.6	50.6 ± 2.1	.13
Normal weight	18.5 BMI 24.9	45.9 ± 1.0	52.5 ± 0.9	<.0001
Overweight	25.0 BMI 29.9	49.2 ± 1.1	49.1 ± 0.6	.90
Obese	30.0 BMI 50.0	46.6 ± 0.9	48.8 ± 0.7	.09

BMI = body mass index; SE = standard error.

[†] Dietary variables represent group means from one in-person 24-hour recall.

[‡] As determined by Proc SurveyReg using weights appropriate for those who provided one in-person 24-hour recall.

Table 4

Dietary Quality, as Measured by the Healthy Eating Index, 2005 (HEI-2005), in Normal Weight Women, Ages 20 to 50 Years, With and Without Migraine, Who Provided a Reliable, in-Person 24-Hour Diet Recall in National Health and Nutrition Examination Survey, 1999-2004^{†,‡,§}

HEI-2005 Total/Component Score	Max Score	Standard for Max Score	Women With Migraine		Women Without Migraine	P value [¶]
			Mean ± SE			
			Normal Weight Women (18.5 BMI 24.9)			
Total fruit	5	0.8 cup eq/1000 kcals	1.7 ± 0.1		2.3 ± 0.1	.002
Whole fruit	5	0.4 cup eq/1000 kcals	1.5 ± 0.2		2.0 ± 0.1	.01
Total vegetables	5	1.1 cup eq/1000 kcals	2.9 ± 0.1		3.2 ± 0.1	.10
DOL	5	0.4 cup eq/1000 kcals	1.0 ± 0.1		1.5 ± 0.1	.001
Total grains	5	3.0 oz eq/1000 kcals	3.9 ± 0.1		4.2 ± 0.1	.01
Whole grains	5	1.5 oz eq/1000 kcals	0.8 ± 0.1		1.0 ± 0.1	.04
Milk	10	1.3 cup eq/1000 kcals	4.8 ± 0.3		5.3 ± 0.2	.11
Meat and beans	10	2.5 oz eq/1000 kcals	7.4 ± 0.2		7.7 ± 0.2	.30
Oil	10	12 grams/1000 kcals	5.0 ± 0.2		5.8 ± 0.2	.01
Saturated fat	10	<7% of energy	5.6 ± 0.3		6.0 ± 0.2	.23
Sodium	10	0.7 grams/1000 kcals	4.7 ± 0.2		4.1 ± 0.1	.04
Calories from SoFAAS	20	20% of energy	6.7 ± 0.4		9.5 ± 0.4	<.0001
HEI-2005 total score	100	sum of components	45.9 ± 1.0		52.5 ± 0.9	<.0001

DOL = dark green and orange vegetables and legumes; SoFAAS = solid fat, alcohol, and added sugars.

[†] Dietary variables represent group means from one in-person 24-hour recall.

[‡] Only normal weight women are examined given the statistically significant difference found in diet quality between those with and without migraine.

[§] As determined by Proc SurveyReg using weights appropriate for those who provided one in-person 24-hour recall.

[¶] To account for multiple comparisons, a Bonferroni adjustment was done. Significance was identified as $P < .004$.