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Adequacy of total usual micronutrient intakes among pregnant women in the United States by level of dairy consumption, NHANES 2003–2016

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Abstract

Background: Dairy products are a rich source of nutrients of public health concern, though most women do not meet the recommended intake of 3 cup-eq/day. **Aim:** The objective of this analysis was to examine micronutrient adequacy among pregnant women in the US by level of dairy consumption. **Methods:** Pregnant women (n = 791) ages 20–44 years in NHANES 2003–2016 were categorized by level of dairy consumption (<1, 1 to <2, 2 to <3, and ≥3 cup-eq/day). Usual micronutrient intakes and prevalence of intakes below the Estimated Average Requirement (EAR) or above the Adequate Intake level (AI) were calculated from food alone and food plus dietary supplements using the National Cancer Institute method. Diet quality was assessed with the Healthy Eating Index 2015 (HEI-2015). **Results:** Pregnant women consuming ≥3 cup-eq/day of dairy were more likely to meet the potassium AI than women consuming lower levels. Compared to women consuming ≥3 cup-eq/day of dairy, women consuming <1 or 1 to <2 cup-eq/day were more likely to have inadequate intake of vitamin D, magnesium, zinc, and vitamin A from foods plus supplements. Compared to women consuming ≥3 cup-eq/day of dairy, women consuming <1 cup-eq/day were more likely to have inadequate intake of calcium and riboflavin. The median urinary iodine concentration (UIC) among pregnant women consuming ≥3 cup-eq/day of dairy was 220 ng/mL compared with median UICs of 98–135 mg/mL among women consuming the lowest levels. Pregnant women consuming ≥3 cup-eq/day of dairy had the highest intake of sodium (mg/day) and saturated fat intake evaluated as a HEI-2015 component. **Conclusions:** Consumption of recommended levels of dairy products may help pregnant women achieve adequate intakes of select micronutrients.

Keywords

Dietary intake, nutrient intake adequacy, maternal diet, pregnancy, dairy products

INTRODUCTION

A balanced and healthy diet is an important factor in pregnancy for both maternal and child health outcomes (Procter and Campbell, 2014). However, the proportions of pregnant women with nutrient intakes below recommended levels are high (Bailey et al., 2019b), indicating that many pregnant women in the US consume suboptimal diets. The 2020–2025 Dietary Guidelines for Americans (DGA) are the first guidelines to include specific recommendations for pregnant and lactating women. Fiber, vitamin D, calcium, and potassium have been identified as nutrients of public health concern for all individuals, including pregnant women (USDHHS/USDA, 2020). Given their critical role in fetal development, additional nutrients of concern during pregnancy include iron, folate, choline, and iodine (USDHHS/USDA, 2020). There has been recent interest in low iodine intake among pregnant women in particular (Ershow et al., 2016), as this nutrient plays a critical role in supporting neurocognitive development of the fetus (DGAC, 2020; IOM, 2001; Zimmermann, 2009). Choline and folate are also involved in fetal neural development, while iron is involved in fetal organ development, including brain

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development (Adamo and Oteiza, 2010; Cerami, 2017; DGAC, 2020; Zeisel and da Costa, 2009).

The DGA provide recommendations for consumption of foods from different food groups to help Americans meet nutrient needs at appropriate energy levels within limits for added sugars, saturated fat, and sodium (USDHHS/USDA, 2020). Dairy foods, which are a component of the DGA dietary patterns, are a rich source of many nutrients, including nutrients of public health concern for pregnant women, namely calcium, vitamin D, potassium, and iodine. Dairy foods are also recognized for making key contributions to dietary intake of vitamin A, phosphorus, riboflavin, vitamin B12, protein, zinc, choline, magnesium, selenium, and iodine in the diets of Americans (USDHHS/USDA, 2015; USDHHS/USDA, 2020). The DGA recommends consumption of 3 cup-equivalents per day (cup-eq/day) of dairy products, which includes fortified soy alternatives, in both the Healthy US Style and Healthy Vegetarian Patterns for most individuals, including pregnant women. Aside from young children, consumption of dairy foods is below recommended intake levels for most Americans (USDHHS/USDA, 2020). Pregnant women are no exception, with a mean dairy foods intake of 1.85 cup-eq/day and an estimated 90% reporting intake below recommended levels between 2013–2016 (DGAC and Data Analysis Team, 2020).

Increased consumption of dairy products during pregnancy may serve an important role in improving nutrient adequacy of many underconsumed micronutrients. The objective of this analysis was to examine nutrient intake adequacy among pregnant women in the US by level of dairy consumption. We hypothesized that adequacy of intake of calcium, vitamin D, potassium, and other key micronutrients in dairy products is higher among pregnant women consuming recommended levels of dairy foods.

METHODS

Data Source and Study Population

This cross-sectional study was conducted with data collected in the National Health and Nutrition Examination Survey (NHANES) and the dietary recall component known as What We Eat in America (WWEIA) in survey cycles from 2003–2004 to 2015–2016 (CDC, 2019). The NHANES, which has been continuously collected since 1999 and is released in 2-year cycles, provides nationally representative nutrition and health data (Ahluwalia et al., 2016). Each NHANES assessment includes an in-person household interview, a health examination in a mobile examination centre (MEC), and a telephone follow-up interview 3–10 days after the MEC examination. Approval for the NHANES data collection was provided by the National Centre for Health Statistics (NCHS) Research Ethics Review Board.

The sample population for this study was pregnant women ages 20–44 years as identified by a positive urine pregnancy test collected during the MEC with a valid day 1 dietary recall as determined by NCHS, excluding lactating women. The final sample of pregnant, non-lactating women in this analysis was 791.

Dietary Intake Data

The WWEIA component of NHANES consists of two 24-h dietary recalls (midnight to midnight); the first dietary recall is collected during the MEC interview and the second is collected during the follow-up telephone interview 3–10 days after the MEC interview. Each recall is collected by trained interviewers using USDA's Automated Multiple-Pass method. In the sample of 791 pregnant, non-lactating women with valid day 1 dietary recalls, 703 also provided a valid day 2 recall.

Categorization by Level of Dairy Consumption

Dairy consumption was quantified in units of cup equivalents per day (cup-eq/day) using the dairy component of the MyPyramid Equivalent Database (MPED 2.0) (Bowman et al., 2008) for NHANES 2003–2004 and the survey specific Food Pattern Equivalents Databases (FPED) for NHANES 2005–2006 through 2015–2016 (Bowman et al., 2020). Consumption of dairy represents all milk (including soy milk with added calcium), yogurt, cheese, and miscellaneous dairy (predominantly whey). For each pregnant woman, total dairy consumption was categorized on day 1 dietary recalls as <1, 1 to <2, 2 to <3, or ≥ 3 cup-eq/day.

Assessment of Micronutrient Intakes

Micronutrient intakes for each respondent were calculated from self-reported food intake (including beverages) and from food plus dietary supplement intakes. The micronutrients examined in this analysis are those identified as key micronutrients contributed by dairy foods, namely calcium, magnesium, phosphorus, riboflavin, vitamin A, vitamin B12, vitamin D, selenium, zinc, potassium, and choline (USDHHS/USDA, 2015).

Information on dietary supplement intake in the past 30 days, including non-prescription antacids that contain calcium and/or magnesium, was collected by trained interviewers during the household interview component of NHANES using the Computer-Assisted Personal Interviewing (CAPI) system. Daily intake of micronutrients from supplements for NHANES 2003–2006 were calculated from reported use of supplements in the 30-day supplement questionnaire and ingredient information in the NHANES Dietary Supplement Database (NHANES-DSD) (CDC, 2019). Daily nutrient intakes from reported use of supplements over the previous 30 days for NHANES 2007–2016 were processed by

NHANES for all nutrients of interest with the exception of supplemental sources of vitamin A. For all surveys included in this analysis, supplements containing ingredients with α-carotene, ß-carotene, and retinol were identified in the NHANES-DSD and used to calculate supplemental intake of vitamin A and retinol in units of micrograms of retinol activity equivalents (mcg RAE) for each respondent using established conversion factors (U.S. FDA, 2019).

Urinary Iodine

Iodine is not included in the nutrient composition database used to process nutrient intakes from the diet so it was not feasible to assess total iodine intakes using the approach applied to other micronutrients in this study. Median urinary iodine concentration (UIC) is a recognized indicator of population level iodine adequacy, where a value below the World Health Organization's (WHO) UIC of 150 μg/L is associated with insufficient intake (WHO, 2013). UIC is measured in spot samples collected during the MEC component from approximately one-third of NHANES participants ages 6 year and older. The UIC data were used to estimate median UIC levels by category of dairy consumption.

Assessment of Diet Quality

Diet quality was assessed with the Healthy Eating Index 2015 (HEI-2015), which was designed to measure adherence to the 2015–2020 DGA (Krebs-Smith et al., 2018). The population ratio method via the NCI-developed SAS macros was applied to estimate the mean total HEI-2015 and dairy, sodium, added sugars, and saturated fats component scores for the total study population and by level of dairy consumption (IOM, 2006). Component scores for sodium, saturated fat, and added sugars were examined as they have been identified as dietary components to restrict (USDHHS/USDA, 2020). Scores range from 0 to 10 based on the following standards: ≥2.0 grams per 1,000 kcal to ≤1.1 gram per 1,000 kcal for sodium, ≥26% of energy to ≤6.5% of energy for added sugars, and ≥16% of energy to ≤8% of energy for saturated fats (Krebs-Smith et al., 2018).

Population Characteristics

The sample population demographic, lifestyle, and reproductive health characteristics and diet quality were examined. Demographic characteristics include age at screening, race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American or other Hispanic, or other race), poverty income ratio (PIR; <1.85, ≥1.85), education status (less than high school, high school diploma, some college, undergraduate degree or higher), and marital status (married, widowed or divorced or separated, never married). Lifestyle characteristics include self-reported smoking status (never smoked, past smoker, current smoker), and physical activity (< 10 min/week, 10 to 150 min/week, ≥150 min/week). Reproductive health characteristics included parity, defined as the number of live births and pre-pregnancy body mass index (BMI), calculated from self-reported pre-pregnancy body weight collected during the in-home interview and standing height measured in the MEC.

Statistical Analyses

Population characteristics of the sample of pregnant women in each dairy consumption category were summarized and compared using ANOVA with Bonferroni adjusted p-values for multiple comparisons for continuous variables, and Pearson Chi-square test for the categorical variables.

Usual intakes (UI) of micronutrients from food alone and food plus dietary supplements were estimated by category of dairy consumption using the National Cancer Institute (NCI) method (Tooze et al., 2010) and the SAS macros developed by NCI for modelling of a single dietary component. The "shrink then add" approach was used to estimate the usual intake from dietary and supplemental sources combined (Bailey et al., 2019a), with covariates including: day of week (weekday/weekend), sequence of dietary recall (day 1 or 2), and whether the participant reported use of dietary supplements in the past 30 days. Balanced repeated replicate weights (Fay adjustment factor = 0.3) based on day 1 dietary recall statistical weights were used for SE estimation (Herrick et al., 2018b).

Prevalence of UIs below the Estimated Average Requirement (EAR) were calculated using the cut-point method to determine the prevalence of inadequate intake for nutrients with an EAR (IOM, 2006; IOM, 2011). Magnesium intake was calculated by age group (20–30 years, 31–44 years) to account for age-specific EARs for women ages 19–30 years and 31–50 years. Comparisons to the Adequate Intake (AI) cannot be used to estimate the prevalence of inadequate nutrient intake of a population (IOM, 2000). For nutrients with only an AI (potassium, choline) (IOM, 2006; NASEM, 2019), the percent of the population above the AI was calculated. For nutrients with a tolerable upper intake level (UL) (calcium, vitamin A (as preformed retinol), vitamin D, phosphorus, magnesium, selenium, zinc, choline) or a chronic disease risk reduction level (CDRR) (sodium), the percent above the UL or CDRR was calculated to determine the prevalence of excess intake (IOM, 2006; IOM, 2011; NASEM, 2019). The UL for magnesium applies to supplemental sources and pharmacologic products only and was not assessed. Bonferroni-adjusted z-tests were used to compare UI for each of the three lowest dairy consumption categories to the UI for the highest dairy consumption category.

Statistical analyses were completed using SAS (version 9.4, SAS Institute Inc., Cary, NC, USA) and STATA

V12.1 (StataCorp, College Station, Texas 77845, USA). All analyses used the appropriate statistical weights provided in NHANES to account for oversampling, survey non-response, and post-stratification and estimates of the standard errors (SEs) and confidence intervals were design adjusted. Estimates are presented as mean ± SE. Statistical significance was defined as Bonferroni-adjusted $p < 0.05$.

In the analysis, the classification of pregnant women into dairy intake categories was based on day 1 dietary recalls. A sensitivity analysis was conducted to evaluate whether women classified in a given category based on their day 1 intake were more likely to be classified in the same category based on their 2-day average intake, which would have provided an alternate approach for categorization. Specifically, pregnant women with valid dietary recalls on both survey days were classified into the four dairy intake categories based on the total number of dairy servings on day 1 and a similar classification was performed using their 2-day average dairy intake. Two analyses were conducted. A Wald test, adjusted for survey design, was used to evaluate whether there is a statistically significant association between the two classifications by comparing the observed weighted counts. In addition, given the ordinal nature of the classifications, Cohen's weighted kappa test was used to test whether the amount of agreement between the two classifications is due to chance alone.

Results

Population Characteristics

The sample of 791 pregnant women was categorized by daily total dairy consumption as <1 (n = 235, 30%), 1 to <2 (n = 209, 28%), 2 to <3 (n = 141, 19%), and ≥3 (n = 206, 22%) cup-eq/day (Table 1). Results of the two analyses conducted to evaluate whether women classified in a given category based on their day 1 intake were more likely to be classified in the same category based on their 2-day average intake showed that the association between the two classification methods was not due to chance (p-value < 0.001).

Age and race/ethnicity of pregnant women were different by level of dairy consumption. Pre-pregnancy BMI did not differ among the categories of dairy intake, and no differences in other sample characteristics were observed across the four levels of dairy consumption.

Mean dairy consumption among all pregnant women in the sample was 2.0 ± 0.08 cup-eq/day, with intake of dairy in units of both cup-eq/day and cup-eq/1000 kcal/day increasing across levels of dairy consumption (Table 2). Usual energy intake was highest among women consuming ≥ 3 cup-eq/day (2707 ± 115.1 kcal/day) followed by women consuming 2 to <3 cup-eq/day (2336 ± 70.7 kcal/day), and 1 to <2 (1945 ± 72.3 kcal/day) and <1 cup-eq/day (1954 ± 56.1 kcal/day).

Pregnant women consuming ≥3 cup-eq/day of dairy foods had higher scores on the saturated fats component of the HEI-2015 compared with those consuming lower levels of dairy (Table 2). Sodium component scores among pregnant women meeting the dairy foods recommendation did not differ from women consuming <1, 1 to <2, or 2 to <3 cup-eq/day of dairy foods. Diet quality as assessed by the HEI-2015 score was higher among pregnant women consuming 1 to <2 cup-eq/day of dairy than women meeting dairy recommendations. HEI-2015 component scores for added sugars did not differ between pregnant women consuming ≥3 cup-eq/day of dairy foods and lower amounts of dairy foods.

Intake and Adequacy of Intake from Food Alone

Usual Nutrient Intakes. Based on contributions from food alone, intakes of calcium, phosphorus, riboflavin, vitamin A, vitamin B12, vitamin D, and potassium were significantly higher among pregnant women consuming ≥3 cup-eq/day of dairy foods than intakes among women consuming all lower levels of dairy foods (Table 3). Pregnant women consuming ≥3 cup-eq/day of dairy foods also had higher intakes of magnesium, selenium, zinc, and sodium than pregnant women consuming <1 or 1 to <2 cup-eq/day of dairy.

Prevalence of Inadequate Nutrient Intakes. Compared to pregnant women consuming ≥3 cup-eq/day, pregnant women consuming <1, 1 to <2, or 2 to <3 cup-eq/day of dairy were more likely to have inadequate intakes of vitamin D (Table 4). Pregnant women consuming <1 or 1 to <2 cup-eq/day of dairy were more likely to have inadequate intakes of magnesium, vitamin A, and zinc compared with pregnant women meeting recommendations for dairy food intakes, while pregnant women consuming <1 cup-eq/day of dairy were more likely to have inadequate intake of calcium and riboflavin compared to pregnant women consuming ≥3 cup-eq/day of dairy.

Prevalence of Nutrient Intakes Above the AI. Pregnant women consuming ≥3 cup-eq/day were more likely to have intakes of potassium above the AI than pregnant women consuming lower levels of dairy foods (Table 4).

Intake and Adequacy of Intake from Food Plus Dietary Supplements

Usual Nutrient Intakes. Intake of calcium, phosphorus, vitamin D, and potassium from food plus dietary supplements was significantly higher among women consuming ≥3 cup-eq/day of dairy compared with pregnant women consuming lower levels of dairy foods (Table 5). Pregnant women meeting recommendations for dairy foods had higher intakes of magnesium, riboflavin, selenium, zinc, and sodium than pregnant women consuming <1 or 1 to <2 cup-eq/day of dairy. Intake of vitamin A

Table 1. Characteristics of the sample population.

Characteristics	Total population (*n* = 791)	Dairy consumption categories (cup-eq/day)[a] <1 (*n* = 235)	1 to <2 (*n* = 209)	2 to <3 (*n* = 141)	≥ 3 (*n* = 206)	P-value[b]
Age (years)	28.5 (0.34)	27.7 (0.48)	29.9 (0.69)	28.9 (0.72)	27.6 (0.47)	0.015
Race/ethnicity (%)						0.012
Mexican American/other Hispanic	20.5 (2.44)	16.6 (3.24)	20.5 (3.49)	19.5 (3.97)	26.9 (5.47)	
Non-Hispanic white	53.0 (3.52)	44.0 (6.02)	53.8 (5.77)	59.9 (6.37)	58.1 (6.15)	
Non-Hispanic black	16.9 (2.25)	27.7 (4.58)	16.9 (3.38)	9.3 (3.16)	8.4 (2.49)	
Other race (including multi-racial)	9.7 (1.55)	11.6 (3.36)	8.8 (3.08)	11.2 (3.44)	6.7 (2.46)	
HH income (poverty income ratio) (%)						0.586
<1.85	40.2 (2.96)	41.1 (4.31)	39.6 (5.60)	33.4 (5.98)	45.6 (7.27)	
≥1.85	59.8 (2.96)	58.9 (4.31)	60.4 (5.60)	66.7 (5.98)	54.4 (7.27)	
Education status (%)						0.873
< High school	18.2 (1.93)	18.9 (4.21)	21.0 (4.19)	13.0 (3.06)	18.2 (3.89)	
High school diploma	17.9 (1.79)	17.7 (3.43)	15.2 (2.96)	21.5 (5.62)	18.3 (3.85)	
Some college	33.7 (2.51)	36.7 (4.98)	29.4 (5.19)	33.2 (6.28)	35.5 (4.73)	
Undergraduate degree or higher	30.3 (2.66)	26.8 (4.74)	34.4 (5.94)	32.3 (5.94)	28.0 (5.55)	
Parity (number of live deliveries) (%)						0.153
0	25.6 (2.69)	25.4 (4.99)	23.0 (4.29)	32.7 (7.13)	23.8 (4.80)	
1	39.6 (2.92)	32.7 (4.74)	36.3 (6.02)	43.9 (7.96)	48.8 (4.83)	
≥2	34.9 (2.76)	41.9 (5.49)	40.8 (6.12)	23.4 (5.27)	27.4 (3.95)	
Marital status (%)						0.290
Married	66.2 (2.56)	57.8 (4.69)	67.8 (4.92)	68.8 (5.08)	73.6 (4.66)	
Widowed/divorced/separated	4.2 (0.86)	5.2 (1.95)	4.6 (2.36)	4.9 (2.28)	1.6 (0.94)	
Never married	29.6 (2.44)	37.1 (4.57)	27.6 (4.25)	26.4 (4.77)	24.8 (4.52)	
Physical Activity (minutes of moderate physical activity equivalent per week) (%)						0.436
< 10 min/week	32.9 (2.9)	39.4 (5.1)	32.5 (4.9)	32.0 (6.1)	25.6 (4.4)	
10 to <150 min/week	27.6 (2.6)	29.4 (4.8)	25.6 (4.7)	27.8 (5.8)	27.6 (4.6)	
≥150 min/week	39.5 (3.3)	31.1 (4.3)	42.0 (5.9)	40.2 (7.2)	46.8 (5.9)	
Smoking (%)						0.147
Never smoked	70.0 (2.6)	76.9 (3.9)	72.0 (5.4)	64.6 (6.4)	62.5 (6.1)	
Past smoker	21.1 (2.5)	12.5 (2.7)	19.7 (4.8)	26.0 (6.3)	30.5 (6.3)	
Current smoker	8.9 (1.5)	10.6 (3.0)	8.3 (2.7)	9.4 (3.4)	7.0 (2.1)	
Use of vitamin/mineral supplements (%)						0.500
No	21.6 (2.1)	25.4 (3.5)	22.4 (4.1)	20.3 (5.5)	16.3 (4.0)	
Yes	78.4 (2.1)	74.6 (3.5)	77.6 (4.1)	79.7 (5.5)	83.7 (4.0)	
Pre-pregnancy BMI status (%)						0.141
Underweight	3.8 (1.0)	4.7 (1.7)	1.2 (0.8)	5.0 (2.0)	5.1 (3.3)	
Normal weight	47.9 (2.9)	49.4 (5.5)	39.9 (6.1)	50.4 (6.5)	53.6 (6.9)	
Overweight	24.0 (2.3)	18.8 (3.7)	37.4 (5.7)	21.2 (5.6)	16.2 (4.0)	
Obese	24.4 (2.6)	27.2 (4.7)	21.6 (5.1)	23.5 (6.0)	25.1 (5.6)	

Abbreviations: *BMI* body mass index; *HH* household.
[a]Values reported as mean or percent (SE). Estimates based on total sample in each dairy consumption category, excluding missing data for parity (n = 80), marital status (n = 1), physical activity (n = 4), pre-pregnancy BMI status (n = 62).
[b]ANOVA with Bonferroni adjusted p-values for multiple comparisons (continuous variables), Pearson Chi-square test (categorical variables).

was higher among women consuming ≥3 cup-eq/day of dairy than intake by women consuming <1 cup-eq/day.

Prevalence of Inadequate Nutrient Intakes. Compared to pregnant women consuming ≥3 cup-eq/day of dairy foods, women consuming <1 or 1 to <2 cup-eq/day of dairy were more likely to have inadequate intakes of magnesium, vitamin A, vitamin D, and zinc (Table 6). Pregnant women consuming <1 cup-eq/day of dairy were also more likely to have inadequate intakes of calcium and riboflavin compared to women meeting recommendations for dairy foods.

Prevalence of Nutrient Intakes Above the AI. Similar to the comparisons based on nutrients from food alone, pregnant women consuming ≥3 cup-eq/day were more likely to have intakes of potassium from food and dietary

Table 2. Energy intake, dairy intake, and diet quality of the sample population.

Characteristics	Total population (*n* = 791)	Dairy consumption categories (cup-eq/day)[a] <1 (*n* = 235)	1 to <2 (*n* = 209)	2 to <3 (*n* = 141)	≥ 3 (*n* = 206)
Usual Energy Intake (kcal/day)[b]	2191 (46.7)	1954 (56.1)	1945 (72.3)	2336 (70.7)	2707 (115.1)
Dairy intake (cup-eq/day)[c]	2.0 (0.08)	0.5 (0.03)	1.4 (0.04)	2.5 (0.03)	4.3 (0.12)
Dairy intake (cup-eq/1000 kcal)[c]	0.9 (0.04)	0.3 (0.02)	0.8 (0.03)	1.2 (0.05)	1.7 (0.07)
Healthy Eating Index (HEI)-2015					
Dairy[d]	4.5 (0.3)	3.8 (0.3)	6.0 (0.3)	7.6 (0.3)	10.0 (0.1)
Sodium	6.0 (0.2)	3.9 (0.5)	4.7 (0.4)	3.8 (0.7)	5.3 (0.5)
Saturated fat[d]	6.1 (0.2)	6.8 (0.4)	7.0 (0.4)	6.0 (0.5)	4.2 (0.4)
Added sugars	7.0 (0.2)	6.0 (0.4)	6.1 (0.4)	6.6 (0.4)	5.9 (0.5)
Total HEI-2015[e]	61.2 (1.1)	58.3 (1.9)	64.7 (2.1)	61.2 (1.8)	57.7 (2.0)

Abbreviations: *HEI* Healthy Eating Index.
[a]Values reported as mean (SE).
[b]Statistically significant difference (Bonferroni adjusted z-tests, $p < 0.05$) between all dairy consumption categories except the two lowest consumption categories 1) <1 cup-eq/day vs 2) 1 to <2 cup-eq/day), p-value <0.05.
[c]Statistically significant difference (Bonferroni adjusted z-tests, $p < 0.001$) between all dairy consumption categories.
[d]Statistically significant difference (Bonferroni adjusted z-tests, $p < 0.05$) between dairy consumption category of ≥3 cup-eq/d and other levels of dairy: 1) vs <1 cup-eq/day, 2) vs 1 to <2 cup-eq/day, and 3) vs 2 to <3 cup-eq/day.
[e]Statistically significant difference (Bonferroni adjusted z-tests, $p < 0.05$) between dairy consumption category of ≥3 cup-eq/d vs 1 to <2 cup-eq/day.

Table 3. Usual intake of nutrients from food alone by dairy consumption category.

Nutrient	Total population[a]	Dairy consumption categories (cup-eq/day)[a] <1	1 to <2	2 to <3	≥ 3
Calcium (mg)[b]	1110 (29.2)	759 (39.8)	976 (37.0)	1254 (33.7)	1641 (44.2)
Magnesium (mg) 20–30 years[c]	288 (7.3)	246 (10.3)	269 (12.5)	313 (16.5)	349 (12.2)
Magnesium (mg) 31–44 years[c]	313 (10.8)	270 (12.5)	298 (17.1)	345 (17.6)	379 (14.9)
Phosphorus (mg)[b]	1404 (27.9)	1141 (41)	1230 (38.7)	1550 (50.3)	1863 (49.9)
Riboflavin (mg)[b]	2.20 (0.056)	1.65 (0.077)	1.91 (0.073)	2.48 (0.087)	3.11 (0.130)
Vitamin A as (µg RAE)[b]	703 (28.8)	508 (35.8)	662 (50.2)	767 (39.2)	971 (55.8)
Vitamin B12 (µg)[b]	5.43 (0.219)	3.92 (0.285)	4.76 (0.275)	6.22 (0.382)	7.68 (0.424)
Vitamin D (µg)[b]	5.7 (0.26)	3.4 (0.29)	4.6 (0.35)	6.3 (0.42)	9.7 (0.60)
Selenium (µg)[c]	111 (2.7)	99 (3.8)	99 (4.1)	128 (5.7)	130 (4.7)
Zinc (mg)[c]	12.1 (0.35)	9.7 (0.43)	10.9 (0.40)	13.9 (0.79)	15.5 (0.76)
Potassium (mg)[b]	2737 (57.4)	2334 (88.2)	2565 (114.8)	2942 (126.1)	3333 (117.7)
Choline (mg)	285 (15.9)	271 (28.8)	258 (31.0)	350 (43.8)	283 (32.8)
Sodium (mg)[c]	3475 (85.7)	3194 (96.4)	3061 (113)	3797 (180.6)	4112 (179.2)

[a]Values reported as mean (SE).
[b]Statistically significant difference (Bonferroni adjusted z-tests, $p < 0.05$) between dairy consumption category of ≥3 cup-eq/d and other levels of dairy: 1) vs <1 cup-eq/day, 2) vs 1 to <2 cup-eq/day, and 3) vs 2 to <3 cup-eq/day.
[c]Statistically significant difference (Bonferroni adjusted z-tests, $p < 0.05$) between dairy consumption category of ≥3 cup-eq/d and other levels of dairy: 1) vs <1 cup-eq/day and 2) vs 1 to <2 cup-eq/day.

supplements above the AI than pregnant women consuming all lower levels of dairy foods (Table 6).

Comparisons with the Tolerable Upper Intake Levels

Compared to pregnant women consuming ≥3 cup-eq/day of dairy foods, the percent of women consuming greater than the CDRR for sodium was lower among women consuming <1 or 1 to <2 cup-eq/day of dairy (93 ± 2.7% and 90 ± 3.8% respectively), but not compared to women consuming 2 to <3 cup-eq/day (>97%). There were no differences in the proportion of pregnant women exceeding the UL for intake of calcium, vitamin A (as preformed retinol), vitamin D, selenium, zinc, or choline from food alone or from food plus dietary supplements among pregnant women consuming ≥3 cup-eq/day of dairy foods compared to all lower levels of dairy.

Urinary Iodine

The median (interquartile range) UIC among pregnant women was 143 [76, 242] ng/mL. Among pregnant

Table 4. Percent below the EAR/above the AI by dairy consumption category from food alone.

			Dairy consumption categories (cup-eq/day)[a]			
		Total population[a]	<1	1 to <2	2 to <3	≥ 3
Nutrient	EAR	Percent below the EAR				
Calcium (mg)[b]	800	23 (5.4)	65 (12.5)	11 (8.2)	<3	<3
Magnesium (mg) 20–30 years[c]	290	54 (3.5)	76 (5.1)	63 (6.4)	40 (7.9)	24 (5.3)
Magnesium (mg) 31–44 years[c]	300	47 (5.6)	69 (6.2)	53 (10.2)	30 (7.8)	19 (5)
Phosphorus (mg)	580	<3	<3	<3	<3	<3
Riboflavin (mg)[b]	1.2	5 (2.2)	13 (5.4)	5 (2.8)	<3	<3
Vitamin A as (μg RAE)[c]	550	31 (4.6)	65 (9.4)	30 (10.3)	14 (5.8)	2 (2.1)
Vitamin B12 (μg)	2.2	<3	6 (2.9)	<3	<3	<3
Vitamin D (μg)[d]	10	90 (2.4)	>97	>97	95 (3.2)	59 (9.1)
Selenium (μg)	49	<3	<3	<3	<3	<3
Zinc (mg)[c]	9.5	25 (3.9)	50 (8.0)	30 (6.1)	5 (3.4)	<3
	AI	Percent above the AI				
Potassium (mg)[d]	2900	39 (2.9)	19 (3.8)	30 (6.0)	50 (6.7)	70 (5.5)
Choline (mg)	450	20 (1.2)	19 (2.7)	17 (2.9)	27 (3.9)	19 (3.5)
Sodium (mg)	1500	>97	>97	>97	>97	>97

Abbreviations: AI Adequate Intake; *EAR* Estimated Average Requirement.
[a]Values reported as mean (SE).
[b]Statistically significant difference (Bonferroni adjusted z-tests, p < 0.05) between dairy consumption category of ≥3 cup-eq/d vs <1 cup-eq/day.
[c]Statistically significant difference (Bonferroni adjusted z-tests, p < 0.05) between dairy consumption category of ≥3 cup-eq/d and 1) vs <1 cup-eq/day and 2) vs 1 to <2 cup-eq/day.
[d]Statistically significant difference (Bonferroni adjusted z-tests, p < 0.05) between dairy consumption category of ≥3 cup-eq/d and other levels of dairy: 1) vs <1 cup-eq/day, 2) vs 1 to <2 cup-eq/day, and 3) vs 2 to <3 cup-eq/day.

Table 5. Usual intake of nutrients from food + supplements by dairy consumption category.

		Dairy consumption categories (cup-eq/day)[a]			
Nutrient	Total population[a]	<1	1 to <2	2 to <3	≥ 3
Calcium (mg)[b]	1324 (37.6)	938 (50.8)	1237 (74.7)	1464 (50.8)	1848 (59)
Magnesium (mg) 20–30 years[c]	303 (8.7)	257 (11.1)	274 (12.7)	334 (17.9)	373 (18.1)
Magnesium (mg) 31–44 years[c]	335 (11.8)	286 (14)	317 (18.6)	376 (21.2)	410 (20)
Phosphorus (mg)[b]	1408 (28)	1145 (42.3)	1231 (38.8)	1555 (52.1)	1867 (51.1)
Riboflavin (mg)[c]	3.95 (0.265)	3.04 (0.272)	3.31 (0.273)	4.21 (0.339)	5.79 (1.019)
Vitamin A (μg RAE)[d]	1336 (56.8)	1072 (76.5)	1287 (159.2)	1504 (97.8)	1617 (104.8)
Vitamin B12 (μg)	24.04 (8.884)	11.13 (1.846)	24.55 (15.057)	12.54 (0.958)	51.42 (35.203)
Vitamin D (μg)[b]	12.8 (0.61)	11.2 (1.24)	10.6 (1.04)	13 (0.81)	17.6 (1.74)
Selenium (μg)[c]	116 (3.1)	101 (3.8)	104 (5.6)	134 (6.2)	137 (5.4)
Zinc (mg)[c]	22.6 (0.73)	19.9 (1.27)	19.5 (1.38)	25.5 (1.62)	27.8 (1.59)
Potassium (mg)[b]	2738 (57.5)	2335 (88.1)	2566 (114.8)	2943 (126.1)	3336 (118.5)
Choline (mg)	286 (15.9)	271 (28.8)	259 (31.2)	351 (43.8)	284 (32.8)
Sodium (mg)[c]	3476 (85.6)	3195 (96.4)	3062 (112.9)	3797 (180.6)	4112 (179.3)

[a]Values reported as mean (SE).
[b]Numerical superscripts indicate statistically significant difference (Bonferroni adjusted z-tests, p < 0.05) between dairy consumption category of ≥3 cup-eq/d and other levels of dairy: 1) vs <1 cup-eq/day, 2) vs 1 to <2 cup-eq/day, and 3) vs 2 to <3 cup-eq/day.
[c]Numerical superscripts indicate statistically significant difference (Bonferroni adjusted z-tests, p < 0.05) between dairy consumption category of ≥3 cup-eq/d and: 1) vs <1 cup-eq/day and 2) vs 1 to <2 cup-eq/day.
[d]Numerical superscripts indicate statistically significant difference (Bonferroni adjusted z-tests, p < 0.05) between dairy consumption category of ≥3 cup-eq/d and <1 cup-eq/day.

women consuming ≥3 cup-eq/day or 2 to 3 cup-eq/day of dairy foods, the median UIC was 220 [125, 440] ng/mL and 198 [89, 242] ng/mL, respectively, while median levels for pregnant women consuming lower levels of dairy were below 150 ng/mL, with a median UIC of 135 [75, 179] ng/mL for women consuming <1 cup-eq/day dairy and 98 [57, 187] ng/mL for women consuming 1 to 2 cup-eq/day.

Discussion

Dietary guidance in the US encourages consumption of 3 servings of dairy products daily as part of healthy eating

Table 6. Percent below the EAR/above the AI by dairy consumption category from food + supplements.

			Dairy consumption categories (cup-eq/day)[a]			
		Total population[a]	<1	1 to <2	2 to <3	≥ 3
Nutrient	EAR	Percent below the EAR				
Calcium (mg)[b]	800	14 (3.2)	39 (7.8)	8 (5.3)	<3	<3
Magnesium (mg) 20–30 years[c]	290	50 (3.4)	71 (5.4)	62 (6.4)	35 (7.3)	20 (4.9)
Magnesium (mg) 31–44 years[c]	300	41 (5.1)	63 (6.4)	46 (9.6)	22 (6.4)	13 (4.4)
Phosphorus (mg)	580	<3	<3	<3	<3	<3
Riboflavin (mg)[b]	1.2	3 (1.3)	8 (3.1)	3 (1.9)	<3	<3
Vitamin A (μg RAE)[c]	550	18 (2.6)	33 (5.2)	21 (6.9)	8 (3.3)	2 (1.2)
Vitamin B12 (μg)	2.2	<3	<3	<3	<3	<3
Vitamin D (μg)[c]	10	42 (2.8)	56 (5.3)	51 (6.3)	35 (5.8)	20 (5.0)
Selenium (μg)	49	<3	<3	<3	<3	<3
Zinc (mg)[c]	9.5	13 (2)	23 (4.2)	18 (4.1)	<3	<3
	AI	Percent above the AI				
Potassium (mg)[d]	2900	39 (2.9)	19 (3.8)	30 (6.0)	50 (6.7)	70 (5.5)
Choline (mg)	450	20 (1.2)	19 (2.7)	17 (2.9)	27 (3.9)	19 (3.5)
Sodium (mg)	1500	>97	>97	>97	>97	>97

Abbreviations: AI Adequate Intake; *EAR* Estimated Average Requirement.
[a]Values reported as mean (SE).
[b]Numerical superscripts indicate statistically significant difference (Bonferroni adjusted z-tests, $p < 0.05$) between dairy consumption category of ≥3 cup-eq/d and <1 cup-eq/day.
[c]Numerical superscripts indicate statistically significant difference (Bonferroni adjusted z-tests, $p < 0.05$) between dairy consumption category of ≥3 cup-eq/d and: 1) vs <1 cup-eq/day and 2) vs 1 to <2 cup-eq/day.
[d]Numerical superscripts indicate statistically significant difference (Bonferroni adjusted z-tests, $p < 0.05$) between dairy consumption category of ≥3 cup-eq/d and other levels of dairy: 1) vs <1 cup-eq/day, 2) vs 1 to <2 cup-eq/day, and 3) vs 2 to <3 cup-eq/day.

patterns designed to meet nutrient needs. However, the majority of the population, including pregnant women, fails to meet this recommendation. The current study examined intake and adequacy of select nutrients among pregnant women by level of dairy consumption (including fortified soy beverages), where the highest level of dairy consumption meets dietary recommendations for dairy foods. Compared to pregnant women consuming ≥3 cup-eq/day of dairy, women consuming lower levels of dairy foods have lower intakes of calcium, vitamin D, and potassium, all of which are recognized as nutrients of public health concern. Compared to pregnant women consuming ≥3 cup-eq/day of dairy, women with the lowest intake of dairy (<1 cup-eq/day) were more likely to have inadequate intakes of calcium and riboflavin, and women consuming <1 cup-eq/day or 1–2 cup-eq/day of dairy were more likely to have inadequate intakes of vitamin D, vitamin A, magnesium, and zinc. While significant differences in nutrient adequacy were observed only between the lowest levels of dairy intake and recommended dairy intakes for these nutrients, the findings suggest that low consumption of dairy products may be a factor in suboptimal intake of these nutrients of public health concern. At all levels of dairy consumption under 3 cup-eq/day, pregnant women were less likely to exceed the potassium AI.

Consumption of the recommended level of dairy foods by pregnant women was associated with higher nutrient intakes, and in turn lower prevalence of inadequate intakes, for many though not all nutrients for which dairy is recognized as a key contributor, therefore largely supporting our hypothesis that adequacy of intake of calcium, vitamin D, potassium, and other key micronutrients in dairy products is higher among pregnant women consuming recommended levels of dairy foods. The absence of any difference in intake of phosphorus, selenium, and vitamin B12 by level of dairy consumption may be explained by the overall low prevalence of inadequate intake of these nutrients, while the absence of any differences in choline intake may be attributed to the relatively low concentration of choline per serving of dairy product (IOM, 2001; USDA/ARS, 2020b).

The majority of pregnant women in this population (78%) reported use of dietary supplements; therefore, it is important to consider contributions from supplements when examining nutrient adequacy in this population. Consistent with other analyses of pregnant women, the prevalence of inadequate nutrient intake is reduced when accounting for contributions of dietary supplements, but use of supplements during pregnancy does not fill all nutrient gaps at the population level (Bailey et al., 2019b). Some nutrients such as potassium are not typically added to supplements, and relatively low (≤ 28%) percentages of pregnant women consume dietary supplements containing choline, iodine, and magnesium (Jun et al., 2020). Therefore, these nutrient needs must be met through the diet.

Dairy products are among the key dietary sources of iodine for the US population, accounting for approximately

43% of dietary iodine in the population of women ages 25–30 years (Abt et al., 2018; Herrick et al., 2018a; Lee et al., 2016). The Recommended Dietary Allowance for iodine is 220 μg for pregnant women (IOM, 2001), while other guidance recommends intake of 250 μg per day (Andersson et al., 2007; WHO, 2007). Recent analyses of milk samples in the US indicate that the mean iodine concentration is 85 ± 5.5 μg per 240 mL serving (Roseland et al., 2020); therefore, intake of approximately 2.5 to 3.0 servings of milk would fulfil the recommended intake for iodine. Mean usual daily iodine intake from all sources by pregnant women age 14–50 years in 2003–2010 was estimated at 332 μg (Juan et al., 2016). More recent data from 2008–2012 show mean daily iodine intake from food at 188.5 μg among all women ages 25–30 years (Abt et al., 2018). Nutrient databases in the US used to estimate nutrient intakes have not included data on iodine, though data are being developed to support future analyses (Patterson et al., 2020). Results from our study show that the subpopulation of pregnant women with the highest consumption of dairy products was not at risk for iodine deficiency based on UIC, indicating that dairy products may contribute to iodine sufficiency for this population of pregnant women.

Pregnant women meeting recommendations for dairy did not have higher diet quality as assessed by the HEI-2015 compared with pregnant women consuming lower levels of dairy foods. In this analysis, pregnant women consuming ≥3 cup-eq/day of dairy had lower saturated fat component scores compared to women consuming lower levels of dairy. The saturated fat component score among pregnant women consuming ≥3 cup-eq of dairy was 4.2, indicating that saturated fat provided 12–13% of energy, and thus exceeds the DGA recommendation of less than 10% of energy from saturated fat (USDHHS/USDA, 2020). Although HEI-component scores for sodium did not differ between pregnant women meeting recommendations for dairy and those consuming lower levels, consumption of 2 or more servings of dairy was associated with increased prevalence of consumption of sodium above recommended levels. Pregnant women consuming ≥3 cup-eq/day of dairy were not more likely to exceed energy intake from added sugars than other levels of dairy consumption. Many dairy foods contain no added sugars, though options including flavoured milks and yogurts are exceptions. Milk and milk products are natural sources of sodium and saturated fat, and cheese is particularly concentrated in both of these components. One cup-eq of low-fat milk, for example, provides approximately 96 mg sodium and 1.4 g saturated fatty acids, while a 1.5 ounce portion of cheddar cheese (equal to 1 cup-eq of dairy), provides 278 mg sodium and 8.2 g saturated fatty acids (USDA/ARS, 2020a; USDA/ARS, 2020b). To help limit intake of saturated fat and sodium from dairy foods, dietary guidance encourages Americans to select fat-free or low-fat milk and yogurt products to meet dairy requirements (USDHHS/USDA, 2020).

Lactose intolerance is recognized as a potential barrier to dairy consumption for all individuals, including pregnant women. The DGA acknowledge that consumers may opt to select dairy products with lower levels of lactose, including lactose free products, for individuals who are lactose intolerant. Fortified soy and other plant-based beverages may also provide an alternative to avoid lactose and provide a nutrient profile similar to milk. Lactose intolerance may also be managed by consuming small portions lactose (up to 12 g), and by consuming dairy foods in combination with other foods (Misselwitz et al., 2019).

A strength of this study is the large nationally representative sample of pregnant women, and the assessment of nutrient intakes from food alone and food plus dietary supplements, as dietary supplements are widely used in this population. As a cross-sectional data analysis, it is not possible to examine causal effects of any of the reported differences. Pregnant women consuming the recommended level of dairy also had higher overall energy intake, and foods other than dairy could be contributing to their nutrient adequacy. The current study did not quantify contributions of dairy foods to total nutrient intakes. Additional limitations of the study include potential misclassification of women into a level of dairy consumption based on one day of recall and self-reports of foods and dietary supplements.

Summary and Conclusions

The majority of pregnant women do not consume the recommended levels of dairy foods. In this study, pregnant women consuming the highest level of dairy products were observed to have increased prevalence of meeting dietary recommendations of select underconsumed micronutrients relative to women consuming the lowest levels of dairy products, though women with higher intake of dairy products also had increased intake of sodium and saturated fat, and total diet quality was not higher compared to women with lower intake of dairy products. Nutrition messaging to pregnant women should further emphasize the importance of selecting recommended types of dairy products along with other nutrient dense foods. Increased consumption of dairy products, primarily in the form of fat-free and low-fat milk and yogurt, may help pregnant women meet micronutrient recommendations during pregnancy.

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Ethics approval and consent to participate

This study is an analysis of the publicly available National Health and Nutrition Examination Survey (NHANES) data. Approval for the NHANES data collection was provided by the National Centre for Health Statistics (NCHS) Research Ethics Review Board. Use of the public use data sets requires neither IRB review nor an exempt determination.

Availability of data and materials

The NHANES data described in the article and used in the analysis are publicly available from the CDC via: https://wwwn.cdc.gov/nchs/nhanes/ContinuousNhanes/Default.aspx.

Authors' contributions

Kelly Higgins, Xiaoyu Bi, Leila Barraj, Carolyn Scrafford, and Mary Murphy contributed to the design and components of data processing and analysis presented in this manuscript, and Benjamin Davis supported data processing and analysis. Mary Murphy and Kelly Higgins wrote the first draft of the manuscript. All authors conducted a final review of the manuscript and provided final approval of the version to be submitted.

Declaration of conflicting interests

The authors declare that they have no competing interests. At the time this study was completed, KAH was employed at Exponent, Inc.; all other authors (XB, BJKD, LMB, CGS, MMM) are employees of Exponent, Inc. Exponent, Inc. provides scientific consulting to the food and beverage industry.

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Abbreviations

24HR	24-h
AI	Adequate intake
BMI	Body mass index
CAPI	Computer-Assisted Personal Interviewing
CDC	Centres for Disease Control and Prevention
CDRR	Chronic disease risk reduction level
DGA	Dietary Guidelines for Americans
DGAC	Dietary Guidelines Advisory Committee
EAR	Estimated average requirement
FPED	Food Patterns Equivalents Database
g	Gram
HEI-2015	Health Eating Index 2015
μg	Microgram
MEC	Mobile Examination Centre
MPED	MyPyramid Equivalent Database
NCHS	National Centre for Health Statistics
NCI	National Cancer Institute
NHANES	National Health and Nutrition Examination Survey
PIR	Poverty income ratio
SE	Standard error
UI	Usual intake
UIC	Urinary iodine concentration
UL	Tolerable Upper Intake Level
US	United States
USDA	United States Department of Agriculture
WHO	World Health Organization
WWEIA	What We Eat in America