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Consumption of Ultra-Processed Foods and Diet Quality Among U.S. Children and Adults

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Abstract

Introduction: Consumption of ultra-processed foods (UPFs) has been linked with higher intakes of added sugars, sodium, and unhealthful fats, but the associations of UPFs with overall diet quality and major food groups are not well known.

Methods: Data were derived from the National Health and Nutrition Examination Survey (2015–2018) including 9,758 adults (aged 20 years) and 5,280 children (aged 2–19 years) with 24-hour dietary recalls (1), with analysis performed in 2020. UPFs were identified using the NOVA classification, with intake (% energy) assessed in quintiles. Diet quality was assessed using the validated American Heart Association (AHA) 2020 continuous primary and secondary diet score and Healthy Eating Index 2015. Poor diet was defined as <40% adherence to the AHA secondary score. Generalized linear regressions estimated relationships between UPF intake and diet quality.

Results: Compared with the lowest quintile of UPF consumption (<39.1% energy), the AHA primary score in adults was progressively lower in Quintile 2 (−1.99, 95% CI= −2.73, −1.25), 3 (−3.60, 95% CI= −4.47, −2.72), 4 (−5.29, 95% CI= −6.28, −4.30), and 5 (−7.24, 95% CI= −8.13, −6.36; >70.7% energy). Corresponding values in children were −2.05 (95% CI= −3.01, −1.09), −2.97 (95% CI= −4.16, −1.79), −3.82 (95% CI= −5.20, −2.44), and −6.22 (95% CI= −7.20, −5.25; >79.0% energy). The estimated proportions of children having poor diet progressively increased from 31.3% (95% CI=26.2%, 36.5%) in Quintile 1 and up to 71.6% (95% CI=68.1%, 75.1%) in Quintile 5. Corresponding proportions of adults having poor diet increased from 18.1% (95% CI=14.3%, 22.0%) in Quintile 1 and up to 59.7% (95% CI=55.3%, 64.1%) in Quintile 5. Findings were similar using the AHA secondary score and Healthy Eating Index 2015 score.

Conclusions: Higher UPF consumption is associated with substantially lower diet quality among children and adults.

INTRODUCTION

Ultra-processed foods (UPFs) are defined as industrial formulations manufactured from substances derived from foods with little, if any, whole food and typically with added flavors, colors, and other additives.[1] Food supplies have dramatically changed over the past 50 years, with UPF products becoming the major source of energy, especially in Western countries, perhaps owing to their higher profit margin and increased shelf life, availability, and convenience.[2,3] In the U.S., UPFs contribute to more than half of total calories consumed.[4] The association between UPF consumption and adverse health outcomes increasingly has been studied.[1] Findings support positive associations of UPF consumption with mortality,[5–8] overweight and obesity,[9] type 2 diabetes,[10] cardiovascular disease,[11] cancer,[12] and depression.[13,14] In addition, one short-term metabolic RCT[15] showed that eating a diet made up of UPFs led to higher calorie consumption and weight gain compared with a diet of whole or minimally processed foods. Studies modeling mediation analysis concluded that differences in nutrient intake (such as sodium, fats, carbohydrates) and dietary food patterns were at least partial drivers of the association between UPF consumption and health outcomes.[8,11,12]

Though studies have suggested inverse associations of UPF consumption with specific nutrients like protein, vitamins, dietary fiber, minerals, and overall nutrient-balanced patterns,[16–19] no prior studies have focused comprehensively on the associations of UPF consumption with dietary quality and major food groups among both children and adults. Understanding these relationships is important for policymakers to set effective strategies to improve diet quality and related health outcomes. To address this gap in knowledge, this study investigates how UPF consumption relates to overall diet quality and major food group consumption among nationally representative samples of U.S. adults and children.

METHODS

Study Population

The National Health and Nutrition Examination Survey (NHANES) is a series of cross-sectional surveys designed to assess health and nutritional status of Americans in a

nationally representative sample using a complex, stratified, and multistage probability sampling method. Details on design, study protocol, and data collection have been reported.[20] The study protocol was approved by the National Center for Health Statistics Research Ethics Review Board, and all participants provided written informed consent. This analysis combined the 2 most recent cycles of NHANES (2015–2016 and 2017–2018). Investigators separately evaluated children (aged 2–19 years) and adults (aged 20 years). Dietary habits were assessed through 1–2 standardized 24-hour dietary recalls per person (Appendix Text 1).[21] Individuals with potentially unreliable dietary intake and young children who were breastfed were excluded (Appendix Figure 1).

Measures

All recorded food items were classified according to NOVA, a food classification system characterizing the extent and purpose of industrial food processing.[1] This classification includes 4 groups: unprocessed or minimally processed foods; processed culinary ingredients; processed foods; and UPFs, products characterized by several stages and various processing techniques and ingredients. Details regarding each food group and examples are provided (Appendix Text 2, Appendix Table 1). If a food item (food code) was deemed to be a homemade recipe, the NOVA classification was applied to the underlying ingredients (U.S. Department of Agriculture National Nutrient Database for Standard Reference Code-SR code) obtained from the U.S. Department of Agriculture Food and Nutrient Database for Dietary Studies. Details have been described previously[4,22] and are provided in Appendix Figure 2.

Diet quality was assessed using American Heart Association (AHA) diet score[23] and Healthy Eating Index (HEI)-2015 score[24] (Appendix Text 3). The AHA score was chosen because it was developed as a measure of cardiovascular health, has been widely validated against diverse clinical outcomes in a range of studies,[23] and is a largely food-based score that is readily translated to the public and policymakers. The AHA diet score was constructed based on the AHA 2020 Strategic Impact Goals for diet, which have been associated with cardiometabolic and other disease outcomes in multiple populations.[23] The 5 primary dietary components of the AHA diet score are total fruits/vegetables, whole grains, fish/shellfish, sugar-sweetened beverages (SSBs), and sodium. The AHA secondary dietary components add nuts/seeds/legumes, processed meat, and saturated fat. The HEI-2015 was chosen because it reflects adherence to key recommendations in the U.S. Dietary Guidelines for Americans.[24] The 9 adequacy components include total fruit, whole fruit, total vegetables, greens and beans, whole grains, dairy, total protein foods, seafood and plant protein, and fatty acids. The 4 moderation components include refined grains, sodium, percentage of energy from added sugars, and percentage of energy from saturated fatty acids. The diet scores range from 0 to 50 for AHA primary score, 0 to 80 for AHA secondary score, and 0 to 100 for the HEI-2015 score (Appendix Tables 2–3). Poor diet was defined as being <40% adherent to AHA secondary score (<32 points).[25] In addition, this study evaluated intake of individual foods/beverages and nutrients linked to major health outcomes as well as those of current policy or general public interest across the distribution of UPFs.[26] Intake of all dietary components were energy adjusted using the residual method

to minimize measurement error in dietary estimates and help account for differences in age, sex, muscle mass, physical activity, and metabolic expenditure.

Covariates included age, sex, race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and other), educational level (less than high school, high school graduate or equivalent, some college, and college graduate), family income (ratio to the federal poverty level: <1.30, 1.30– 1.84, 1.85–2.99, and 3.00), and BMI levels. Educational level among children refers to their parental education attainment. The ratio to the federal poverty level was calculated by dividing family income by the poverty guidelines, specific to family size, as well as the appropriate year and state, set by HHS.[27]

Statistical Analysis

All statistical analyses were performed using Stata, version 14. All analyses used the NHANES dietary weights, which account for differential probabilities of selection and the complex survey design to create nationally representative estimates. The 1-day value was used for individuals with single recalls and 2-day means for those with 2 recalls. The significance level was 0.05, and all tests were 2-sided.

This study presents quintiles of UPF contribution to total energy intake (% energy). Proportions were calculated to describe the characteristics of participants overall and by quintiles of UPF (% energy). Linear regression models were used to assess the associations between UPF in quintiles and diet quality scores with adjustments of the aforementioned covariates. Logistic regression models were used to assess the associations of UPF with poor diet quality with the same covariate adjustments as in linear models. Predicted margins were calculated and showed the standardized prevalence of poor diet quality by quintiles of the contribution of UPF (% energy; based on the model coefficients and standardized to the distribution of the model covariates within the analytic sample).

RESULTS

This study included 5,919 children and 10,064 adults from NHANES cycles 2015–2016 and 2017–2018. Characteristics of these participants across quintiles of UPF (% energy) are shown (Table 1). Among both children and adults, participants who were male, non-Hispanic White or Black, and had lower education were among the highest UPF consumers; Hispanic and other race/ethnicity and college graduates were among the lowest consumers. Whereas in children UPF consumption increased with age, an opposite trend was observed in adults. In adults, the highest income stratum consumed less UPF, compared with lower incomes.

The contribution of UPF across quintiles of consumption (% energy) and their relationships with predicted means of AHA and HEI-2015 total and component scores are shown in Table 2 and Appendix Table 4. Among both children and adults, the multivariable-adjusted dietary scores decreased significantly across increasing quintiles of UPF intake. For example, compared with the lowest quintile of UPF consumption in children (<50.2% energy), the multivariable-adjusted score for the highest quintile (>79.0% energy) was −6.22 (95% CI= −7.20, −5.25) lower for the AHA primary score and −9.96 (95% CI= −11.4, −8.50) lower

for the AHA secondary score. Among adults, compared with the lowest quintile of UPF consumption (<39.1% energy), the diet score for the highest quintile (>70.7% energy) was −7.24 (95% CI= −8.13, −6.36) lower for the primary AHA and −12.6 (95% CI= −13.8, −11.4) lower for the secondary AHA score. Similar results were found for HEI-2015 scores among both children and adults.

Relatively large differences by quintiles of the contribution of UPF (% energy) were observed among diet scores for fruits and vegetables, SSBs, nuts/seeds/legumes, refined grains, and added sugars (Tables 2, Appendix Table 4). For example, among children, compared with the lowest quintile of UPF consumption, the multivariable-adjusted added sugar score for progressively higher quintiles was −1.02 (95% CI= −1.24, −0.79), −2.06 (95% CI= −2.36, −1.76), −2.64 (95% CI= −2.99, −2.30), and −3.20 (95% CI= −3.48, −2.91).

This study also examined the association of UPF with poor diet quality, characterized by <40% adherence to the AHA secondary diet score. The ORs and predicted margins (standardized prevalence) across quintiles of the contribution of UPF (% energy) are shown in Appendix Table 5. After adjustment for covariates, both children and adults consuming higher UPFs had significantly higher odds of having poor diet quality. The estimated proportions of children having poor diet quality almost doubled across quintiles, increasing from 31.3% of children (95% CI=26.2%, 36.5%) in the lowest, 43.9% (95%CI= 38.2%, 49.5%) in the second, 47.8% (95%CI=42.2%, 53.3%) in the third, 55.9% (95%CI=50.2%, 61.7%) and up to 71.6% (95% CI=68.1%, 75.1%) in the highest quintile (Appendix Figure 3). The predicted proportions of adults having poor diet quality were 18.1% (95% CI=14.3%, 22.0%) for the lowest, 29.4% (95% CI=25.7%, 33.0%) for the second, 38.9% (95% CI=34.0%, 43.8%) for the third, 47.8% (95% CI=43.1%, 52.4%) for the fourth, and 59.7% (95% CI=55.3%, 64.1%) for the highest quintile (Appendix Figure 3).

The progressive magnitudes of associations were similar across quintiles of UPF intake by sociodemographic subgroups but were more pronounced among minorities, lower education and household income levels, and higher BMI levels (Figures 1–2, Appendix Table 5). For example, the predicted proportions of adults in low-income household (ratio to the federal poverty level <1.30) having poor diet quality were 22.9% (95% CI=15.4%, 30.4%) for the lowest, 35.4% (95% CI=29.4%, 41.5%) for the second, 45.6% (95% CI=37.7%, 53.5%) for the third, 57.1% (95% CI=49.9%, 64.4%) for the fourth, and 72.6% (95% CI=67.0%, 78.3%) for the highest quintile. The corresponding values among adults in high-income household (ratio to the federal poverty level ≥3.0) were 17.6% (95% CI=12.4%, 22.9%) for the lowest, 25.9% (95% CI=20.7%, 31.1%) for the second, 35.3% (95% CI=27.7%, 42.9%) for the third, 41.4% (95% CI=35.9%, 46.8%) for the fourth, and 48.5% (95% CI=43.1%, 53.9%) for the highest quintile.

The multivariable-adjusted associations of the contribution of UPFs (% energy) with major food groups and nutrients were additionally shown for children and adults (Appendix Figure 4 and Appendix Tables 6–7). The consumption of healthy foods such as fruits, vegetables, nuts/seeds, and fish significantly decreased with increasing consumption of UPFs. For example, among adults, the predicted marginal mean intake for total fruits were 1.28 (95% CI=1.17, 1.40), 1.02 (95% CI=0.91, 1.12), 0.88 (95% CI=0.79, 0.97), 0.76 (95% CI=0.67,

0.85), and 0.55 (95% CI=0.50, 0.60) servings/day corresponding to the quintiles. Similar differences were observed among children. On the other hand, consumption patterns for unhealthy foods such as refined grains, SSBs, and added sugar were reversed. For example, among adults, the predicted marginal mean intake for SSBs was 0.58 (95% CI=0.44, 0.72), 0.76 (95% CI=0.66, 0.85), 0.97 (95% CI=0.86, 1.08), 1.30 (95% CI=1.13, 1.47), and 1.73 (95% CI=1.54, 1.93) servings/day corresponding to the quintiles.

DISCUSSION

Using nationally representative data, this study assessed the relationships of UPF consumption with overall dietary quality and major food groups/nutrients among both U.S. children and adults. The findings provide strong evidence that higher UPF consumption is associated with poor diet quality. Across quintiles of UPF consumption, the percentage of children with a poor-quality diet rose from 31.3% to 71.6%, and from 18.1% to 59.7% among adults. Among dietary components relatively large differences were found across quintiles of UPF consumption for added sugars, SSBs, refined grains, fruits and vegetables, and nuts/seeds/legumes. To the authors' knowledge, this is the first study to examine the relationship of UPF consumption with overall diet quality scores, component scores, and major food groups/nutrients among children and adults, separately.

This study suggests that as consumed calories from UPFs increases, consumption of healthy foods progressively decreased while that of unhealthy food progressively increased. The percentage of children and adults having poor diet quality doubled from the lowest quintile to the highest quintile of UPF consumption. Similar differences were observed in food groups and nutrients. These findings not only reflect the differences associated with percentage calories contributed by UPFs but also provide opportunities and strategic targets on reducing UPF intake and improving diet quality.

The findings also provide insightful knowledge on disparities in diet quality associated with UPF intake by population subgroups. For example, by race/ethnicity, the proportions of adults having poor diet quality tripled among non-Hispanic Whites and Blacks while the corresponding proportion quadrupled among Hispanics from the lowest to the highest quintile of UPF consumption. Similar differences were observed by household income levels, education levels, and BMI levels. These results may provide additional information about efficient and cost-effective interventional strategies on subgroups to reduce poor diet and promote healthy diet equity.

Juul et al.[19] analyzed U.S. grocery purchasing data from the National Household Food Acquisition and Purchase Survey 2012–2013 and observed that households purchasing the most UPFs (>67.9% energy) scored 10.7 points lower on the HEI-2015 than those purchasing the least (<48.4% energy) (p<0.001) and were furthest from meeting the 2015–2020 Dietary Guidelines for Americans for total fruits, whole fruits, total vegetables, greens and beans total protein food, seafood and plant protein, refined grains, sodium, and added sugars except whole grains. The present investigation builds upon and extends these prior results by assessing individual dietary consumption (rather than household-level food purchases) and foods from all sources (rather than only grocery stores). Though

largely consistent with these results, in this study, whole grain scores decreased with UPF consumption in both children and adults, dairy scores decreased with UPF consumption among children, and fatty acid ratio and saturated fats scores decreased among adults. Using data from the 2000–2012 Nielsen Homescan Panel, Poti and colleagues[33] observed that >90% of highly processed household-level food purchases exceeded saturated fat, sugar, and sodium 2010 Dietary Guidelines for Americans recommendations.

The findings are consistent with prior studies from Brazil, Chile, Mexico, Colombia, France, the United Kingdom, Australia, and Canada showing that increases in the dietary share of UPFs are associated with lower nutritional quality.[17,28–33] Furthermore, the nutritional quality in those studies was evaluated based on either individual nutrient such as free sugars; total, saturated, and trans fats; sodium; fiber; potassium; and protein or nutrient-derived profiles such as a nutrient-balanced-pattern Principal Component Analysis factor score. In addition, prior studies included both children and adults as a whole sample. This study provides important information about differences in the association of contribution of UPFs (% energy) with poor diet quality, separately for children and adults. Concerns regarding the increased share of UPFs in diets have led to various policy actions to discourage consumption of UPFs and promote freshly prepared meals. For example, avoidance of UPFs is a central component of recent national dietary guidelines issued in Brazil, Uruguay, Israel, and Peru.[34,35] France has set the goal of reducing UPF consumption by 20% between 2018 and 2021 in their public health nutritional policy.[36] Policy actions to reduce the consumption of unhealthy processed foods include a junk food tax implemented in Mexico and Hungry,[37] and "black box" warning labels on packaged foods that contain high levels of added sugars, added salt, and added saturated fat in Chile and Mexico.[38,39]

Several studies have investigated and supported the positive association of UPFs with adverse health outcomes. For example, large prospective cohort studies carried out in France, Spain, Brazil, and U.S. suggested that an increased proportion of UPFs in the diet is associated with a higher risk of total mortality, obesity, hypertension, cardiovascular disease, diabetes, and cancer.[5–8,10–12,40,41] A randomized trial conducted by NIH researchers showed that, over 2 weeks, higher UPF consumption led to increased intake of calories and weight gain, compared with unprocessed or minimally processed foods, even when the overall meals were designed to be well matched for energy density, fat, protein, carbohydrate, sugar, sodium, and fiber.[15] This study suggested that limiting consumption of UPFs may be an effective strategy for obesity prevention and treatment.

Strengths of this study include use of a nationally representative sample, assessment of different validated dietary quality scores, and use of NOVA classification, the most widely studied system to characterize food processing. The largely food-based AHA scores are also more easily incorporated into public messages and therefore have utility for public health.

Limitations

First, self-reported dietary information is subject to error, owing to memory and reporting bias leading to inaccurate individual food, nutrient, and energy (especially absolute) estimates.[42] Yet, interview-administered 24-hour recalls using a computer-assisted personal interview system were used, and results were further adjusted for total energy, each of

which reduce measurement error. Also, diet recalls account and weight for days of the week to provide unbiased population average estimates. Second, no single gold standard is established to assess overall diet quality. However, this study assessed both AHA and HEI-2015 diet scores, both of which have been validated against clinical outcomes, and the general patterns for each were similar across quintiles of UPF. Third, reporting bias where people may under-report consumption of less-healthy processed foods may lead to an underestimation of UPF consumption. Fourth, although NHANES collects considerable information on different foods, these data are not consistently determined for all food items and may also not incorporate all brand names or updated, market-representative nutrient information, which could lead to overestimation or underestimation of UPF. Inaccuracies can also arise for mixed dishes, for which Food and Nutrient Database for Dietary Studies uses standard recipes based on assumptions about the types and quantities of ingredients consumed when respondents are unable to provide this information, or does not disaggregate some homemade recipes.[43] In this analysis, all food items were classified independently by 2 researchers, reducing the chances of classification errors; and in cases of doubt, most food items were classified conservatively (as non-ultra-processed), which could lead to UPF underestimation.[4]

CONCLUSIONS

Higher consumption of UPFs is associated with substantially lower diet quality in the U.S. among both adults and children.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

ACKNOWLEDGMENTS

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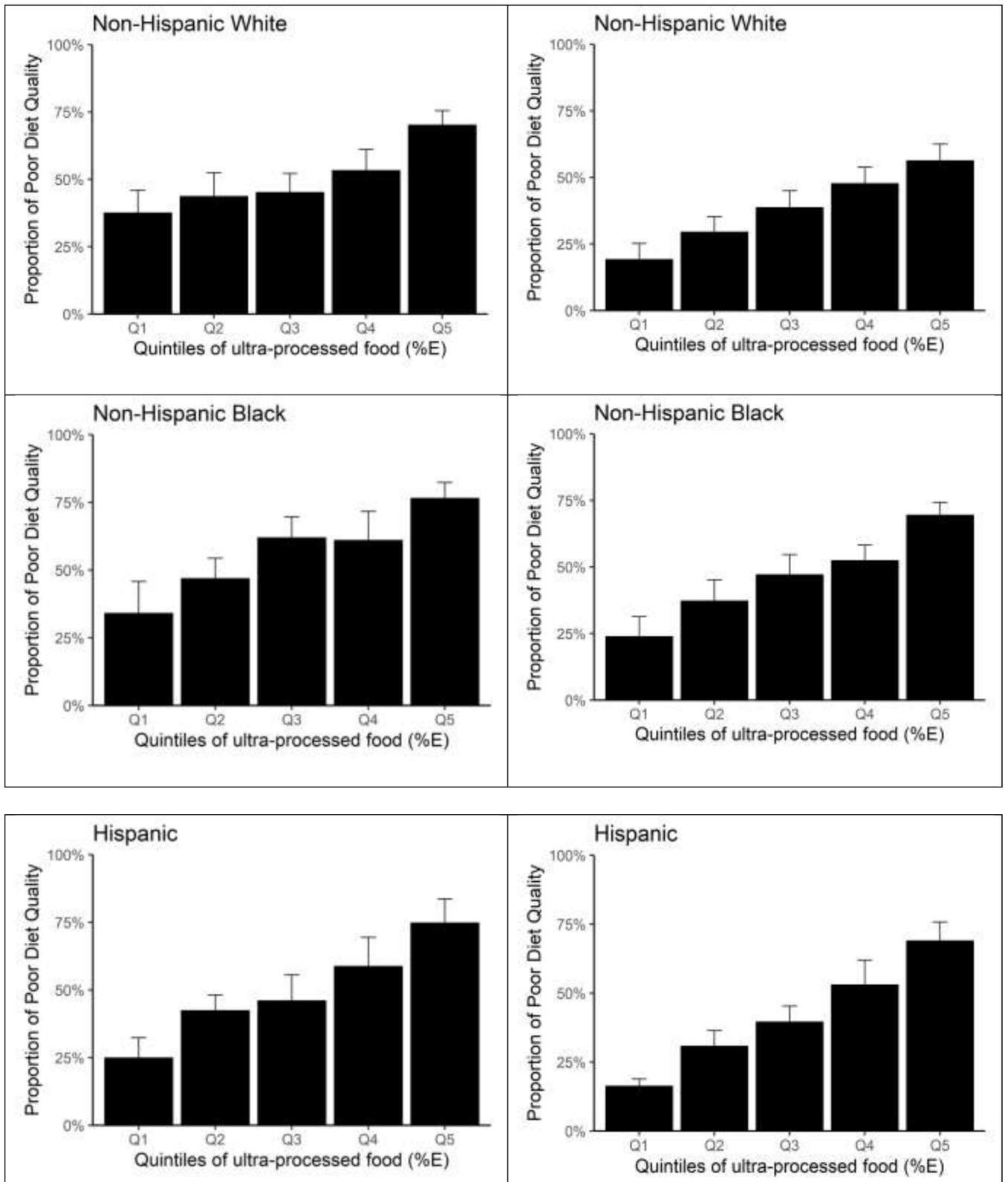
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Children

Adults

Figure 1.
Predicted marginal proportions of poor diet quality across quintiles of ultra-processed food consumption (%E) among U.S. children (aged 2–19 years) and adults (aged 20 years) by race/ethnicity, NHANES 2015–2018.

Notes: Data were adjusted for NHANES survey weights to be nationally representative. Error bars indicate 95% CIs.

NHANES, National Health and Nutrition Examination Survey.

Children

Adults

Poverty to income ratio<1.30

Poverty to income ratio<1.30

Poverty to income ratio:1.30-1.85

Poverty to income ratio:1.30-1.85

Poverty to income ratio:1.85-2.99

Poverty to income ratio:1.85-2.99

Figure 2.
Predicted marginal proportions of poor diet quality across quintiles of ultra-processed food consumption (%E) among U.S. children (aged 2–19 years) and adults (aged 20 years) by household income, NHANES 2015–2018.
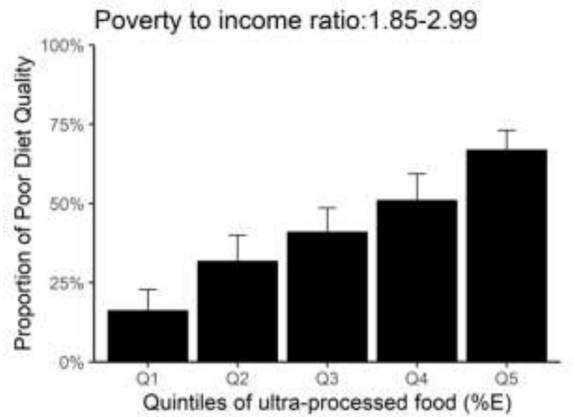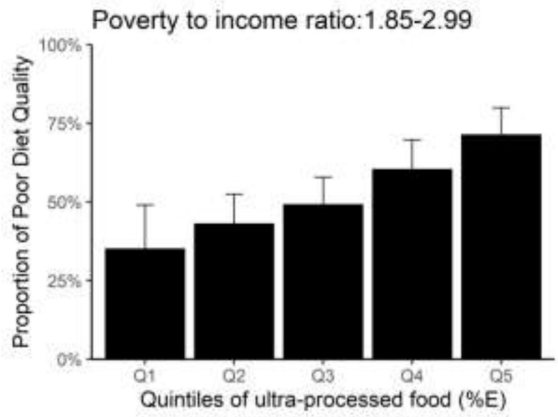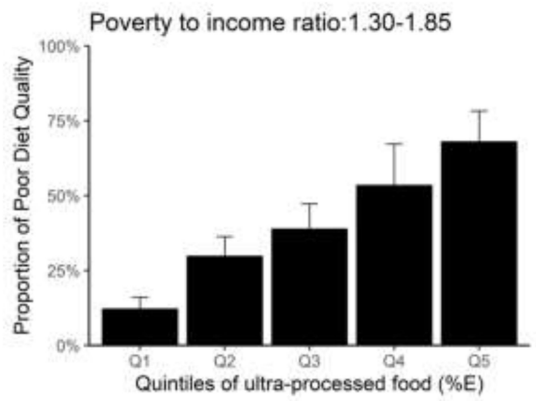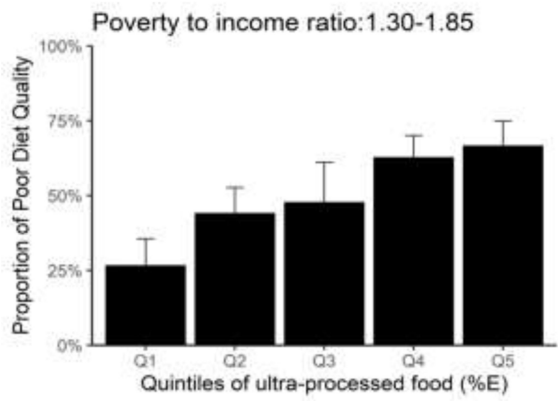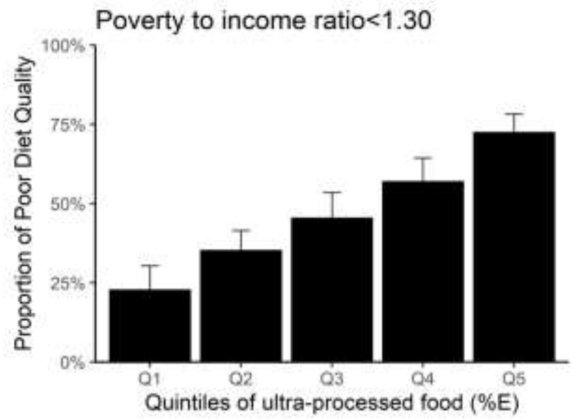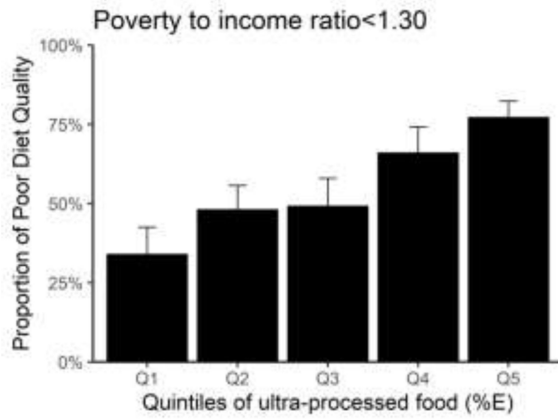
Notes: Data were adjusted for NHANES survey weights to be nationally representative. Error bars indicate 95% CIs.

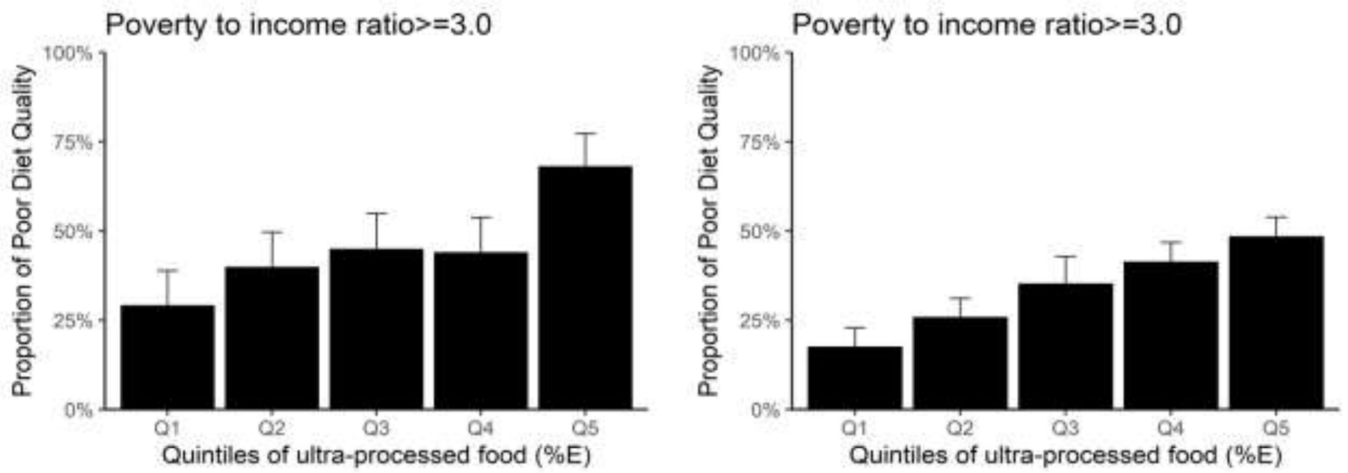NHANES, National Health and Nutrition Examination Survey.

Table 1.

Sociodemographic Characteristics of Study Participants by Quintiles of the Contribution of Ultra-Processed Foods to Total Energy Intake, NHANES 2015–2018[a]

Variable	Overall	Q1	Q2	Q3	Q4	Q5
Children	N=5,280	n=1,157	n=1,063	n=998	n=985	n=1,077
Age, years						
2 to 5	21.4 (20.1, 22.8)	31.5 (27.7, 35.7)	27.7 (24.6, 31.1)	19.6 (16.4, 23.2)	15.9 (13.0, 19.2)	12.4 (9.73, 15.6)
6 to 11	33.4 (31.7, 35.3)	25.3 (22.0, 29.0)	28.5 (25.2, 32.2)	39.2 (35.1, 43.4)	38.3 (34.5, 42.1)	35.8 (31.7, 40.2)
12 to 19	45.1 (42.4, 47.9)	43.1 (37.6, 48.8)	43.7 (38.8, 48.9)	41.2 (36.3, 46.4)	45.8 (41.8, 49.9)	51.8 (47.9, 55.7)
Sex						
Male	50.9 (48.7, 53.0)	45.7 (42.3, 49.1)	49.4 (44.2, 54.5)	49.5 (44.9, 54.1)	56.0 (51.6, 60.3)	53.8 (50.4, 57.3)
Female	49.1 (47.0, 51.3)	54.3 (50.9, 57.7)	50.6 (45.5, 55.8)	50.5 (45.9, 55.1)	44.0 (39.7, 48.4)	46.2 (42.7, 49.6)
Race/Ethnicity						
Non-Hispanic White	50.7 (43.8, 57.6)	39.4 (31.4, 48.1)	48.6 (42.1, 55.1)	54.7 (47.1, 62.2)	55.6 (47.9, 63.0)	55.2 (45.9, 64.3)
Non-Hispanic Black	13.3 (9.87, 17.8)	10.7 (7.6, 14.7)	10.8 ('.77, 14.8)	13.7 (9.86, 18.8)	13.5 (9.77, 18.5)	18.0 (12.5, 25.1)
Hispanic	24.7 (19.5, 30.7)	32.8 (25.5, 41.1'	*'9.6 (23.1, 37.1)	20.8 (15.8, 27.0)	21.7 (16.8, 27.5)	18.5 (13.8, 24.4)
Other	11.3 (9.3, 13.6)	17.1 (13.3, 21.8)	11.0 (8.27, 14.5)	10.7 (7.96, 14.2)	9.20 (6.92, 12.1)	8.25 (5.96, 11.3)
Education level[b]						
Less than high school graduate	17.6 (14.1, 21.7)	21.6 (16.2, 28.2)	20.5 (15.3, 26.9)	18.6 (14.7, 23.3)	13.1 (10.2, 16.6)	14.1 (11.0, 18.0)
High school graduate or GED or some college	54.3 (50.8, 57.8)	47.1 (41.4, 52.9)	53.0 (47.7, 58.2)	50.3 (45.0, 55.5)	55.8 (50.2, 61.3)	65.1 (60.0, 69.9)
College graduate or above	28.2 (23.9, 32.8)	31.3 (24.0, 39.7)	26.6 (21.2, 32.7)	31.1 (25.3, 37.6)	31.1 (25.7, 37.0)	20.8 (15.8, 26.8)
Ratio of family income to poverty level						
<1.30	32.0 (28.2, 36.1)	31.9 (26.5, 37.9)	33.7 (28.4, 39.5)	29.9 (24.6, 35.8)	28.9 (24.6, 33.5)	35.7 (29.9, 41.9)
1.30 to 1.849	12.9 (11.0, 15.2)	13.3 (6.82, 17.6)	13.7 (10.3, 17.9)	13.2 (10.6, 16.3)	10.4 (8.73, 12.4)	14.1 (10.4, 18.9)
1.85 to 2.99	19.1 (16.6, 21.9)	22.1 (18.2, 26.6)	18.4 (14.7, 22.6)	16.0 (12.2, 20.7)	20.0 (16.8, 23.7)	19.0 (15.1, 23.6)
3.0	36.0 (30.9, 41.4)	32.7 (26.5, 39.6)	34.2 (28.4, 40.6)	40.9 (34.1, 48.0)	40.7 (34.4, 47.2)	31.2 (24.5, 38.9)
BMI categories						
Underweight	3.61 (2.73, 4.75)	3.55 (2.35, 5.31)	3.84 (2.27, 6.44)	4.33 (2.51, 7.38)	3.07 (1.64, 5.68)	3.25 (2.14, 4.93)
Normal weight	59.1 (56.7, 61.3)	63.2 (58.8, 67.4)	59.3 (55.9, 62.7)	56.4 (51.1, 61.5)	57.3 (53.6, 60.9)	59.1 (54.1, 63.8)
Overweight	16.0 (14.7, 17.4)	15.1 (11.6, 19.3)	15.2 (12.2, 18.7)	18.5 (14.8, 23.0)	17.2 (13.8, 21.2)	14.0 (11.7, 16.6)
Obese	21.3 (19.3, 23.6)	18.2 (15.3, 21.5)	21.6 (18.2, 25.5)	20.8 (17.3, 24.7)	22.5 (18.9, 26.5)	23.7 (20.0, 27.8)
Adults	N=9,758	n=2,277	n=1,945	n=1,877	n=1,780	n=1,879
Age, years						
20 to 44	43.8 (41.2, 46.4)	39.9 (35.6, 44.3)	44.6 (40.1, 49.2)	39.4 (35.1, 43.8)	45.4 (40.5, 50.4)	49.6 (46.1, 53.0)
45 to 64	35.4 (33.6, 37.2)	40.1 (36.0, 44.5)	33.3 (29.7, 37.1)	36.8 (32.2, 41.6)	31.5 (28.6, 34.6)	35.1 (31.7, 38.6)

Variable	Overall	Q1	Q2	Q3	Q4	Q5
65	20.9 (18.9, 22.9)	19.9 (17.1, 23.2)	22.0 (18.7, 25.8)	23.8 (20.3, 27.8)	23.1 (20.3, 27.8)	15.4 (13.1, 17.9)
Sex						
Male	48.0 (46.8, 49.4)	46.4 (43.6, 49.2)	47.5 (43.8, 51.3)	48.8 (44.9, 52.6)	48.9 (44.9, 52.9)	48.8 (46.1, 51.5)
Female	51.9 (50.6, 53.2)	53.6 (50.8, 56.4)	52.5 (48.7, 56.2)	51.2 (47.4, 55.1)	51.1 (47.1, 55.1)	51.2 (48.5, 53.9)
Race/Ethnicity						
Non-Hispanic White	63.2 (58.3, 67.8)	51.9 (45.3, 58.4)	62.9 (56.6, 68.8)	65.6 (59.5, 71.2)	68.5 (63.9, 72.8)	67.2 (61.8, 72.2)
Non-Hispanic Black	11.3 (8.87, 14.2)	9.41 (7.29, 12.1)	9.21 (7.05, 11.9)	11.0 (8.64, 14.0)	11.5 (8.71, 15.1)	15.2 (11.4, 20.1)
Hispanic	15.4 (12.4, 19.0)	19.0 (14.8, 24.0)	17.9 (14.2, 22.4)	16.6 (12.6, 21.5)	12.5 (9.59, 16.2)	11.1 (8.96, 13.7)
Other	10.1 (8.32, 12.2)	19.8 (16.1, 24.0)	9.91 (6.39, 11.4)	6.84 (5.21, 8.94)	7.42 (5.83, 7.02)	6.45 (4.98, 8.31)
Educational level						
Less than high school graduate	12.2 (10.6, 14.1)	14.0 (11.6, 16.8)	12.2 (10.1, 14.6)	11.6 (9.08, 14.8)	10.6 (8.65, 12.9)	12.8 (10.3, 15.9)
High school graduate or GED	24.6 (22.7, 26.5)	20.5 (17.1, 24.4)	20.4 (17.8, 23.1)	23.7 (20.9, 26.8)	26.2 (22.6, 30.3)	32.1 (28.3, 36.1)
Some college	32.1 (31.2, 34.1)	26.5 (23.8, 29.4)	31.1 (26.9, 35.6)	31.9 (27.7, 36.3)	36.8 (33.9, 40.9)	34.2 (30.8, 37.8)
College graduate or above	31.1 (27.4, 35.0)	39.0 (32.9, 45.5)	36.4 (31.6, 41.5)	32.7 (28.1, 37.7)	26.4 (21.9, 31.4)	20.9 (17.3, 24.9)
Ratio of family income to poverty level						
<1.30	20.8 (19.0, 22.8)	23.4 (19.6, 27.8)	19.0 (16.2, 22.1)	18.3 (16.2, 20.6)	19.8 (16.3, 23.9)	23.7 (20.7, 27.0)
1.30 to 1.849	10.8 (9.47, 12.3)	10.4 (8.28, 13.1)	9.56 (7.43, 12.2)	10.9 (8.57, 13.7)	10.6 (8.63,12.9)	12.7 (10.0, 15.9)
1.85 to 2.99	18.6 (16.5, 20.8)	15.2 (12.3, 18.7)	19.1 (15.6, 23.2)	19.5 (16.9, 22.4)	19.6 (16.7, 22.9)	19.3 (16.5, 22.6)
3.0	49.8 (46.4, 53.1)	50.9 (45.5, 56.3)	52.3 (47.4, 57.2)	51.4 (46.5, 56.2)	50.0 (44.6, 55.4)	44.3 (39.9, 48.7)
BMI categories						
Underweight	1.49 (1.18, 1.88)	1.29 (0.82, 2.03)	1.25 (0.64, 2.42)	1.47 (0.81, 2.65)	1.30 (0.64, 2.60)	2.13 (1.59, 2.84)
Normal weight	25.0 (23.1, 27.0)	29.4 (26.6, 32.3)	28.9 (25.6, 32.5)	23.4 (20.1, 27.1)	22.4 (19.6, 25.6)	21.0 (18.5, 23.7)
Overweight	31.6 (30.0, 33.1)	35.9 (33.2, 38.7)	31.9 (28.5, 35.5)	32.1 (28.2, 36.2)	29.3 (26.7, 32.1)	28.6 (24.7, 32.7)
Obese	41.9 (39.4, 44.5)	33.4 (30.3, 36.8)	37.9 (33.8, 42.1)	43.0 (38.7, 47.4)	47.0 (43.7, 50.2)	48.3 (44.3, 52.3)

Notes: Children Q1= 50.2%; Q2=50.2%–61.2%; Q3=61.2%–70.0%; Q4=70.0%–79.0%; Q5= 79.0%. Adults Q1=<39.1%; Q2=39.1%–50.2%; Q3=50.6%–60.1%; Q4=60.1%–70.7%; Q5=>70.7%.

[a] Data were weighted to be nationally representative.

[b] For children, education refers to parental/household educational levels. Due to the existing categorization in NHANES 2017–2018 (less than high school, high school graduate or GED or some college, and college graduate and above), authors combined the high school graduate or GED and some college together for previous NHANES cycle 2015–2016.

NHANES, National Health and Nutrition Examination Survey.

Table 2.

Associations of Quintiles of the Contribution of Ultra-Processed Foods to Total Energy Intake with American Heart Association Dietary Scores Among U.S. Children and Adults, NHANES 2015–2016 and 2017–2018[a]

Variable	Regression coefficients (95% CI)					Predicted margins (95% CI)				
	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5
Children										
AHA primary component goals										
Primary total diet score	0.0 (ref)	−2.05 (−3.01, −1.09)	−2 2.97 (−4.16, −1.79)	−3.82 (−5.20, −2.44)	−6.22 (−7.20, −5.25)	21.6 (20.6, 22.6)	19.5 (18.7, 20.4)	18.6(17.8, 19.5)	17.8 (16.7, 18.8)	15.4 (14.8, 15.9)
Fruits and vegetables	0.0 (ref)	−0.88 (−1.23, −0.54)	−1.47 (−1.77, −1.16)	−1.67 (−2.11, −1.23)	−2.64 (−3.02, −2.26)	5.14 (4.78, 5.50)	4.26 (4.01, 4.51)	3.68 (3.36, 3.89)	3.47 (3.19, 3.76)	2.50 (2.37, 2.63)
Whole grain	0.0 (ref)	−0.01 (−0.42, 0.41)	0.16 (−0.32, 0.63)	−0.04 (−0.58, 0.50)	−0.58 (−0.96, −0.20)	2.92 (2.60, 3.24)	2.91 (2.51, 3.31)	3.08 (2.75, 3.40)	2.88 (2.47, 3.29)	2.34 (2.09, 2.58)
Fish and shellfish	0.0 (ref)	−0.54 (−0.89, −0.20)	−0.68 (−1.06, −0.30)	−0.67 (−1.07, −0.26)	−0.93 (−1.29, −0.57)	1.35 (1.04, 1.67)	0.81 (0.63, 0.99)	0.67 (0.46, 0.88)	0.69 (0.44, 0.93)	0.43 (0.26, 0.59)
Sugar-sweetened beverages	0.0 (ref)	−0.65 (−1.13, −0.18)	−1.18 (−1.71, −0.65)	−1.84 (−2.37, −1.30)	−2.34 (−2.78, −1.90)	7.99 (7.61, 8.37)	7.33 (6.97, 7.70)	6.81 (6.39, 7.22)	6.15 (5.70, 6.60)	5.65 (5.17, 6.13)
Sodium	0.0 (ref)	0.04 (−0.25, 0.32)	0.20 (−0.13, 0.53)	0.39 (−0.02, 0.79)	0.27 (−0.08, 0.62)	4.20 (3.92, 4.47)	4.23 (3.97, 4.49)	4.40 (4.17, 4.62)	4.58 (4.33, 4.84)	4.46 (4.28, 4.64)
AHA secondary component goals										
Secondary total diet score	0.0 (ref)	−3.79 (−5.46, −2.12)	−5.13 (−6.90, −3.36)	−6.52 (−8.39, −4.65)	−9.96 (−11.4, −8.50)	37.9 (36.5, 39.2)	34.1 (32.5, 35.7)	32.8 (31.4, 34.1)	31.4 (29.9, 32.8)	27.9 (27.3, 28.6)
Nuts, seeds, and legumes	0.0 (ref)	−0.31 (−0.87, 0.25)	−0.75 (−1.28, −0.22)	−1.17 (−1.83, −0.51)	−1.85 (−2.30, −1.41)	3.95 (3.56, 4.33)	3.63 (3.13, 4.14)	3.19 (2.72, 3.67)	2.78 (2.27, 3.28)	2.09 (1.77, 2.42)
Processed meat	0.0 (ref)	−0.87 (−1.50, −0.23)	−0.95 (−1.50, −0.39)	−0.81 (−1.33, −0.29)	−1.22 (−1.68, −0.76)	7.88 (7.47, 8.28)	7.01 (6.50, 7.51)	6.93 (6.53, 7.33)	7.06 (6.66, 7.46)	6.65 (6.25, 7.05)
Saturated fat, % energy	0.0 (ref)	−0.56 (−1.19, 0.07)	−0.46 (−1.07, 0.15)	−0.72 (−1.28, −0.16)	−0.67 (−1.21, −0.12)	4.47 (3.95, 4.99)	3.91 (3.53, 4.29)	4.01 (3.65, 4.38)	3.75 (3.47, 4.03)	3.81 (3.58, 4.03)
Adults										
AHA primary component goals										
Primary total diet score	0.0 (ref)	−1.99 (−2.73, −1.25)	−3.60 (−4.47, −2.72)	−5.29 (−6.28, −4.30)	−7.24 (−8.13, −6.36)	23.6 (22.9, 24.3)	21.6 (21.0, 22.2)	20.0 (19.2, 20.8)	18.3 (17.4, 19.2)	16.3 (15.6, 17.1)
Fruits and vegetables	0.0 (ref)	−0.91 (−1.17, −0.64)	−1.37 (−1.71, −1.02)	−1.86 (−2.18, −1.53)	−2.61 (−2.90, −2.31)	5.89 (5.62, 6.16)	4.99 (4.77, 5.21)	4.53 (4.27, 4.78)	4.04 (3.74, 4.33)	3.29 (3.08, 3.49)

Variable	Regression coefficients (95% CI)					Predicted margins (95% CI)				
	Q1	Q2	Q3	Q4	Q5	Q1	Q2	Q3	Q4	Q5
Whole grain	0.0 (ref)	−0.08 (−0.46, 0.30)	−0.10 (−0.50, 0.30)	−0.36 (−0.69, −0.02)	−0.49 (−0.80, −0.18)	2.81 (2.51, 3.11)	2.73 (2.50, 2.96)	2.71 (2.42, 2.99)	2.45 (2.17, 2.74)	2.32 (2.01, 2.63)
Fish and shellfish	0.0 (ref)	−0.29 (−0.63, 0.05)	−0.78 (−1.16, −0.40)	−0.70 (−1.22, −0.18)	−1.39 (−1.94, −0.84)	2.47 (2.11, 2.83)	2.18 (1.85, 2.51)	1.69 (1.38, 2.0)	1.77 (1.35, 2.19)	1.08 (0.80, 1.36)
Sugar-sweetened beverages	0.0 (ref)	−0.78 (−1.14, −0.43)	−1.38 (−1.77, −0.98)	−2.47 (−2.95, −1.99)	−2.93 (−3.35, −2.51)	8.52 (8.23, 8.81)	7.74 (7.46, 8.02)	7.15 (6.78, 7.51)	6.05 (5.57, 6.53)	5.60 (5.23, 5.97)
Sodium	0.0 (ref)	0.06 (−0.17, 0.29)	0.03 (−0.22, 0.28)	0.09 (−0.21, 0.39)	0.17 (−0.07, 0.41)	3.88 (3.73, 4.04)	3.95 (3.72, 4.17)	3.92 (3.73, 4.10)	3.98 (3.73, 4.22)	4.06 (3.85, 4.26)
AHA secondary component goals										
Secondary total diet score	0.0 (ref)	−4.09 (−5.12, −3.08)	−6.91 (−8.13, −5.69)	−9.92 (−11.3, −8.55)	−12.6 (−13.8, −11.4)	42.6 (41.7, 43.6)	38.5 (37.6, 39.5)	35.7 (34.6, 36.9)	32.7 (31.5, 33.9)	30.0 (29.1, 31.0)
Nuts, seeds, and legumes	0.0 (ref)	−0.30 (−0.73, 12.9)	−1.01 (−1.45, −0.58)	−1.42 (−1.89, −0.96)	−2.12 (−2.62, −1.62)	5.40 (5.02, 5.78)	5.10 (4.74, 5.46)	4.39 (4.01, 4.77)	3.98 (3.58, 4.37)	3.27 (3.02, 3.54)
Processed meat	0.0 (ref)	−0.65 (−1.03, −0.27)	−1.09 (−1.55, −0.63)	−1.70 (−2.18, −1.22)	−1.66 (−2.11, −1.21)	8.06 (7.78, 8.34)	7.41 (7.12, 7.69)	6.97 (6.62, 7.32)	6.36 (5.92, 6.79)	6.40 (6.04, 6.76)
Saturated fat, % energy	0.0 (ref)	−1.15 (−1.56, −0.74)	−1.21 (−1.59, −0.83)	−1.50 (−1.92, −1.08)	−1.57 (−1.93, −1.20)	5.60 (5.29, 5.92)	4.45 (4.16, 4.75)	4.39 (4.16, 4.62)	4.10 (3.86, 4.35)	4.04 (3.80, 4.27)

[a]Data were weighted to be nationally representative, and adjusted for age, sex (male, female), race/ethnicity (non-Hispanic White, non-Hispanic Black, Hispanic, and others), education (less than high school, high school graduate or GED, some college, or college graduate or above), ratio of family income to poverty (<1.30, 1.30–1.849, 1.85–2.99, and 3.0), and BMI categories (underweight, normal weight, overweight, and obese). Individuals with missing data on education (n=242 for children, n=10 for adults) and income (n=461 for children, n=1,038 for adults) were excluded.

NHANES, National Health and Nutrition Examination Survey.