# Ultra-processed food consumption among US adults from 2001 to 2018

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**ABSTRACT**

**Background:** Accumulating evidence links ultra-processed foods to poor diet quality and chronic diseases. Understanding dietary trends is essential to inform priorities and policies to improve diet quality and prevent diet-related chronic diseases. Data are lacking, however, for trends in ultra-processed food intake.

**Objectives:** We examined US secular trends in food consumption according to processing level from 2001 to 2018.

**Methods:** We analyzed dietary data collected by 24-h recalls from adult participants (aged >19 y; $N = 40{,}937$) in 9 cross-sectional waves of the NHANES (2001–2002 to 2017–2018). We calculated participants' intake of minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods as the relative contribution to daily energy intake (%kcal) using the NOVA framework. Trends analyses were performed using linear regression, testing for linear trends by modeling the 9 surveys as an ordinal independent variable. Models were adjusted for age, sex, race/ethnicity, education level, and income. Consumption trends were reported for the full sample and stratified by sex, age groups, race/ethnicity, education level, and income level.

**Results:** Adjusting for changes in population characteristics, the consumption of ultra-processed foods increased among all US adults from 2001–2002 to 2017–2018 (from 53.5 to 57.0 %kcal; *P*-trend < 0.001). The trend was consistent among all sociodemographic subgroups, except Hispanics, in stratified analyses. In contrast, the consumption of minimally processed foods decreased significantly over the study period (from 32.7 to 27.4 %kcal; *P*-trend < 0.001) and across all sociodemographic strata. The consumption of processed culinary ingredients increased from 3.9 to 5.4 %kcal (*P*-trend < 0.001), whereas the intake of processed foods remained stable at ∼10 %kcal throughout the study period (*P*-trend = 0.052).

**Conclusions:** The current findings highlight the high consumption of ultra-processed foods in all parts of the US population and demonstrate that intake has continuously increased in the majority of the population in the past 2 decades. *Am J Clin Nutr* 2022;115:211–221.

**Keywords:** NHANES, NOVA, processed foods, dietary intake, nutrition surveillance

## Introduction

Worldwide, diets and food supplies are increasingly based on ultra-processed foods, defined as industrially manufactured, ready-to-eat/heat formulations that are made with multiple additives and largely devoid of whole foods (1, 2). The consumption of ultra-processed foods has been postulated as a key driver of the global rise in chronic diet-related diseases (3), and a growing body of evidence, including large, carefully conducted cohort studies, links ultra-processed foods to obesity, cardiometabolic diseases, and cancer (4, 5). Furthermore, nationally representative studies have consistently found that diets high in ultra-processed foods are grossly nutritionally unbalanced (6–9). As a result, processing level has emerged as an important new dimension of diet quality that reflects a qualitative aspect of food that is often ignored in traditional nutrient-focused metrics.

Although the diets of most Americans remain of suboptimal nutritional quality (10), intakes of certain nutrients and food groups improved in the 21st century (11). Notably, the intake of added sugar decreased from 1999 to 2016, whereas the consumption of whole grains, whole fruit, plant protein (primarily from whole grains and nuts), and polyunsaturated fat increased (11). Furthermore, energy intake from sugar-sweetened beverages nearly halved from 2003 to 2016 (12). Although these dietary changes might signal a reduced consumption of ultra-processed foods, they are also compatible with changes in the types of ultra-processed foods consumed (e.g., an increased intake of artificially sweetened beverages and whole-grain snack foods). Indeed, the proportion of US adults consuming low-calorie sweeteners increased from 26.9% in 1999–2000 to 32.0%

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Abbreviations used: AMPA, Automated Multiple-Pass Method; FNDDS, Food and Nutrient Database for Dietary Studies.

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in 2007–2008 (13). Furthermore, an analysis in the NHANES found that intake of ultra-processed foods increased significantly between 2007 and 2012 (14). More recent trends in ultra-processed food consumption remain unknown.

Understanding dietary trends is essential to inform priorities and policies to improve diet quality and prevent diet-related chronic diseases. Likewise, it is crucial to identify how trends in diet vary according to specific sociodemographic subgroups to see if health disparities are worsening or improving and inform public health efforts to address disparities. Nutrition surveillance regarding diet processing level is currently lacking. To address these knowledge gaps, we examined secular trends in dietary intakes according to processing level from 2001 to 2018 across diverse sociodemographic strata in the US adult population.

## Methods

### Study design and population

The current study used data from NHANES survey cycles 2001–2002 through 2017–2018. NHANES is a cross-sectional, nationally representative survey designed to assess the health and nutritional status of the US population (15). The survey uses a complex, stratified, multistage probability cluster sampling design to obtain a nationally representative sample of 5000 noninstitutionalized civilian US residents annually (16).

For the purpose of the present analyses, we restricted the analytical sample to adults aged 20 y and older with a valid in-person dietary recall. A total of 50,201 participants were in the appropriate age span. Of these, we excluded 5,700 individuals who lacked valid dietary data, 2 individuals reporting no food or drink intake, and 3,562 individuals missing data for 1 or more covariates. The final analytical data set included 40,937 participants. A flowchart of the creation of the analytical sample is presented in **Figure 1**. Each survey cycle was treated as a separate study population and point in time. As the current study consists solely of secondary analyses of publicly available data, it was exempt from institutional review board review.

### Data collection

Data on demographics, socioeconomic characteristics, and health behaviors were self-reported during an interview by trained personnel in the respondents' homes. Data on dietary intake were collected by 24-h dietary recall interviews performed by trained interviewers at a mobile examination center (17). One single, in-person recall was carried out in cycles prior to 2003, whereas later survey cycles included an in-person recall followed by a telephone-based recall 3–10 d later (17). From 2003 and onward, recalls were performed using the validated USDA's Automated Multiple-Pass Method (AMPM) (18–20).

### Food consumption according to NOVA processing level

On the basis of the NOVA framework that classifies food items according to the extent and purpose of food processing, we allocated all food items recorded in NHANES 2001 to 2018 into 4 mutually exclusive food groups: *1*) "minimally processed foods," including fresh, dry, or frozen fruit or vegetables, grains, legumes, meat, fish, and milk; *2*) "processed culinary ingredients," including table sugar, oils, fats, and salt; *3*) "processed foods," including foods such as canned fish and vegetables and artisanal cheeses, which are manufactured by adding salt, sugar, oil, or other processed culinary ingredients to minimally processed foods; and *4*) "ultra-processed foods," including instant and canned soups; reconstituted meat and fish products; ready-made sauces, gravies, and dressings; French fries and other premade potato products such as chips; ready-to-eat and dry-mix desserts such as pudding; confectionary; sweet and savory snack foods, including granola bars and protein bars and sugar-sweetened or artificially sweetened beverages including soda, fruit drinks, presweetened tea and coffee, energy drinks, and dairy-based drinks; flavored and/or sweetened yogurt; industrially manufactured cakes, cookies, and pies; dry cake and pancake mixes; industrially manufactured breads; sweet breakfast cereals; frozen and shelf-stable plate meals; ice cream, frozen yogurt, and ice pops; and meatless patties and fish sticks (1).

As previously described (21, 22), we classified foods by considering the NHANES variables "Main Food Description"; "Additional Food Description," which describes foods (food codes); and "SR Code Description," which describes the underlying ingredients of foods (SR codes), as well as "Combination Food Type" and "Source of Food." When foods were judged to be a handmade recipe, we applied the classification to the underlying ingredients to ensure a more accurate classification.

We obtained SR codes for each survey cycle from the corresponding versions of the USDA's Food and Nutrient Database for Dietary Studies (FNDDS) and used Food Code energy values provided by NHANES to calculate energy intake from each NOVA food group. For handmade recipes, we used data from both FNDDS and the USDA National Nutrient Database for Standard Reference, Release 20–28 and Legacy, to calculate energy values of the underlying ingredients (SR codes). These calculations are described in detail elsewhere (22).

Using dietary data for the day 1 (in-person) 24-h dietary recall, we calculated each participant's intake of *1*) minimally processed foods, *2*) processed culinary ingredients, *3*) processed foods, and *4*) ultra-processed foods as the relative contribution to daily energy intake (percentage of total energy). We also calculated the intake of specific food subgroups within each NOVA food group (percentage of total energy).

### Outcomes

The primary outcomes were relative energy intake from minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods. The secondary outcomes were relative energy intake of specific food subgroups within each NOVA food group.

### Definition of covariates

Sociodemographic covariates of interest included sex, age (continuous and categorized as 20–39 y, 40–59 y, and ≥60 y), race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other race including multiracial), education level (less than high school, high school degree/general equivalency diploma, some college, college graduate or above), and family

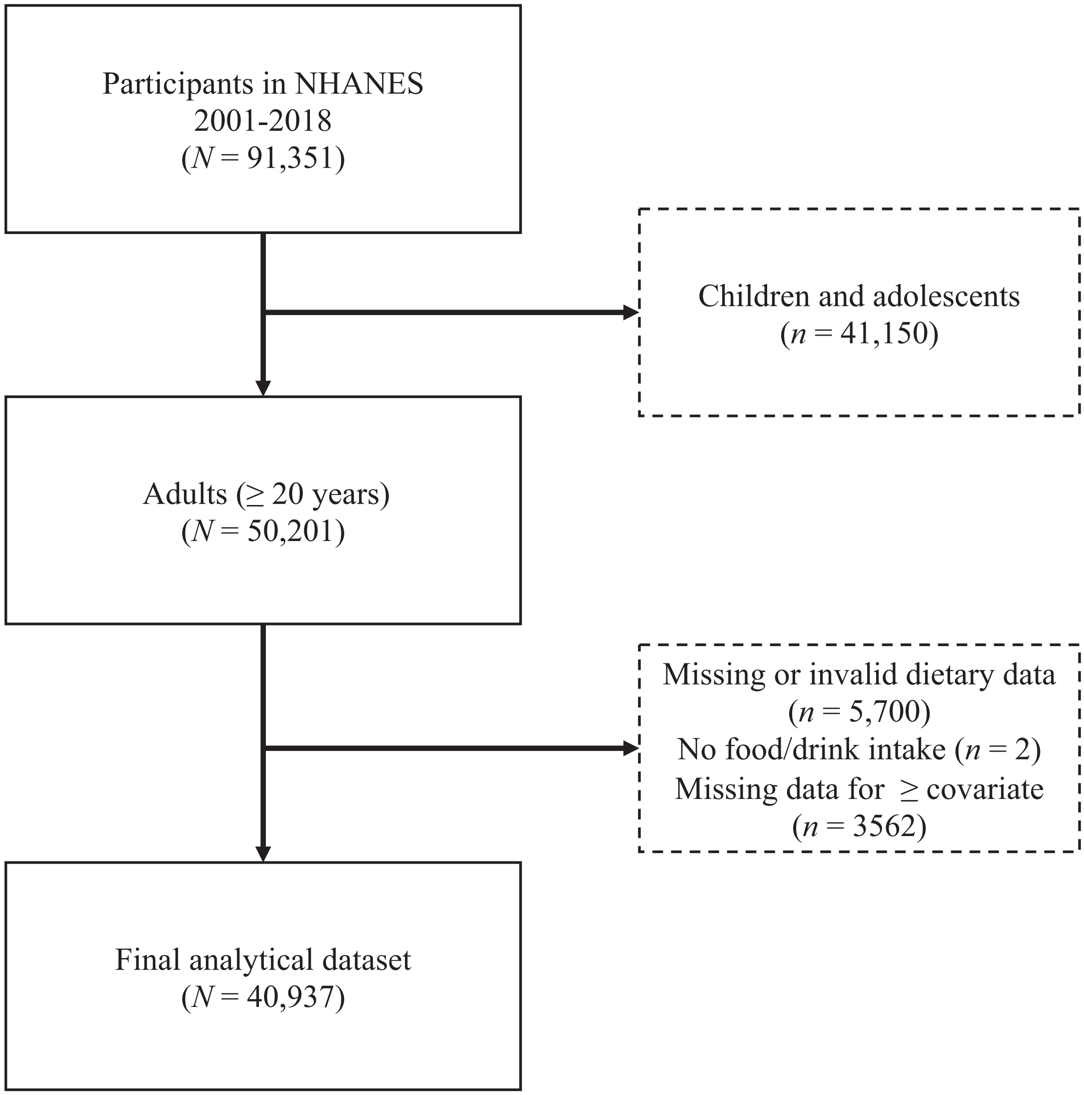


**FIGURE 1** Creation of the analytical sample for the current study from NHANES 2001–2018.

poverty income ratio, defined as the ratio of family income to the year-specific federal poverty threshold (categorized as <130%, 130–349%, and ≥350% of the federal poverty threshold).

### Statistical analyses

Descriptive statistics (means and standard deviations; percentages and frequencies) were computed for sociodemographic and dietary characteristics of the respondents of each survey cycle. We evaluated linear trends in the mean intake of each NOVA food group (percentage of total energy) by calculating *P*-trend using unadjusted and multivariable adjusted linear regression, modeling the 9 survey cycles as an ordinal independent variable. We also performed fractional polynomial regression models to evaluate the presence of nonlinear trends. All multivariable adjusted models were adjusted for age, sex, race/ethnicity, education level, and income to assess trends in food consumption independent of potential changes in population structure over the study period. As a sensitivity analysis, we performed additional models adjusted for smoking and physical activity level in the overall sample.

Trends were reported for the full sample and stratified by sex, age groups, race/ethnicity, education level, and income level, as food choices and eating patterns may differ between these subgroups. We tested for heterogeneous trends among population subgroups by survey-weighted Wald tests, incorporating a multiplicative term between 2-y survey cycle and subgroup (e.g., sex × year) in the regression models. As a secondary analysis, we determined trends in the mean intake of specific subgroups within each NOVA food group in the overall sample. To account for multiple comparisons, we adjusted the *P*-trend values in stratified analyses and analyses of NOVA subgroups by calculating false discovery rate *q* values (23). The false discovery rate is the expected proportion of rejections that are type I errors (false rejections).

Analyses were conducted using the NHANES sample weights to account for oversampling of certain populations, nonresponse, and population coverage (16). We used the Taylor series linearization variance approximation procedure to account for the complex sample design of NHANES in the variance estimation. Fractional polynomial regressions were performed without survey weighting as STATA does not support the use of weights for this procedure. All analyses were performed using Stata/SE 15.1 (StataCorp). Statistical significance was set to $\alpha = 0.1$ for tests of interaction and $\alpha = 0.05$ for all other analyses.

## Results

Survey-weighted characteristics of NHANES participants aged ≥20 y at each survey cycle are presented in **Table 1**. Across all cycles, ∼48% of participants were male and 52% were female. Over time, the mean age (44.9 y in 2001–2002 compared with 48.1 y in 2017–2018) and the proportion of individuals aged ≥60 y increased, whereas the proportion of younger individuals decreased. Education level also increased, with the proportion of college graduates increasing from 26.7% in 2001–2002 to 30.0% in 2017–2018.

### Trends in dietary intakes according to NOVA food groups in the overall population

The survey-weighted, multivariable adjusted mean intakes of foods per NOVA food groups and subgroups for each survey cycle are presented in **Table 2**. The average intake of ultra-processed foods increased from 53.5 %kcal in 2001–2002 to 57.0 %kcal in 2017–2018 (*P*-trend < 0.001). Among subgroups of ultra-processed foods, there was an increased consumption of instant/canned soups; cakes, cookies, and pies; confectionary; ultra-processed meat and fish items; frozen/shelf-stable meals; sandwiches and hamburgers; and frozen pizzas. In contrast, there was a significant trend toward decreased consumption of sodas, noncarbonated sweet drinks, breakfast cereals, bread, ice cream, and other ultra-processed foods (soy products such as meatless patties and fish sticks; ultra-processed sauces and dips; margarine; sugar substitutes, sweeteners, and syrups other than 100% maple syrup; and distilled alcoholic drinks).

From 2001–2002 to 2017–2018, the average consumption of minimally processed foods decreased from 32.7 to 27.4 %kcal (*P*-trend < 0.001). The trend toward decreased consumption was driven by decreasing intakes of minimally processed meat and poultry, dairy products, "other minimally processed foods" (unsalted/unsweetened nuts and seeds, yeast, unsweetened dried fruits, coffee and tea, coconut water and meat, homemade soups and sauces, flours and tapioca), roots, and legumes. The consumption of processed culinary ingredients increased from 3.9 to 5.4 %kcal between 2001–2002 and 2017–2018 (*P*-trend < 0.001). Specifically, intakes of animal fats and plant oils increased over time, whereas the consumption of sugar decreased. There was a borderline significant trend toward increased consumption of processed foods over the study period (*P*-trend = 0.052), which reached statistical significance after additional adjustment for smoking and physical activity (*P*-trend = 0.045). Adjustment for smoking and physical activity did not alter the observed trends of the remaining NOVA food groups (results not shown). A positive quadratic trend in the intake of processed culinary ingredients was identified in fractional polynomial regression models, indicating that consumption rose at an increasing rate over time (results not shown). We did not find evidence of nonlinear time trends in the intake of the remaining NOVA food groups.

### Trends in dietary intakes according to NOVA food groups across demographic groups

**Figure 2** shows multivariable adjusted trends in intakes according to NOVA food groups stratified by sex. A general exchange between ultra-processed and minimally processed foods (i.e., the difference between the 2 groups) is depicted by the dashed line in this and subsequent figures. Mean intake of ultra-processed foods increased to a greater extent among males (+4.3 %kcal, *P*-trend = 0.001) than among females (+2.7 %kcal, *P*-trend = 0.002; *P*-interaction sex × year = 0.06), whereas the consumption of minimally processed foods decreased similarly among both sexes (*P*-trend = 0.001; *P*-interaction = 0.98). Intake of processed food increased among females only (+0.9 %kcal; *P*-trend = 0.006; *P*-interaction sex × year = 0.0062).

Multivariable adjusted consumption trends by NOVA food groups stratified by age and race/ethnicity are presented in **Figure 3.** Ultra-processed food consumption increased significantly among all age groups over the study period (*P*-interaction age × year = 0.15). Consumption of minimally processed foods decreased the most among adults aged 60 y and older (–7.4 %kcal, *P*-trend = 0.001), followed by middle-aged adults (–5.8 %kcal, *P*-trend = 0.001) and younger adults (–3.7 %kcal, *P*-trend = 0.001; *P*-interaction age × year = 0.0137). Notably, older adults had the highest consumption of minimally processed foods (33.0 %kcal) and lowest consumption of ultra-processed foods (51.7 %kcal) in 2001–2002, yet the lowest intake of minimally processed foods (25.6 %kcal) and highest intake of ultra-processed foods (57.4 %kcal) in 2017–2018. Trends in intake of processed culinary ingredients and processed foods did not differ by age group (*P*-interaction age × year = 0.46 and 0.71, respectively).

From 2001 to 2018, consumption of minimally processed foods decreased among all races/ethnicities (*P*-trend = 0.001; *P*-interaction race/ethnicity × year = 0.50). In stratified analyses, the mean intake of ultra-processed foods increased among non-Hispanic whites and non-Hispanic blacks (*P*-trend = 0.001; *P*-interaction race/ethnicity × year = 0.31). Throughout the study period, Hispanic adults consumed significantly more minimally processed foods and significantly less ultra-processed foods compared with non-Hispanic whites and blacks. A trend toward increased consumption of processed foods was observed among non-Hispanic whites only (+0.6 %kcal; *P*-trend = 0.016; *P*-interaction race/ethnicity × year = 0.07). Intake of processed culinary ingredients increased the most among non-Hispanic blacks (+1.8 %kcal), followed by Hispanics (+1.5 %kcal) and non-Hispanic whites (+1.2 %kcal; *P*-trend = 0.001 for all groups; *P*-interaction race/ethnicity × year = 0.0298).

### Trends in dietary intakes according to NOVA food groups across education and income levels

**Figure 4** shows multivariable adjusted trends in intake by NOVA food groups stratified by education and household income.

**TABLE 1** Demographic characteristics of US adults aged 20 y and older in each NHANES cycle, 2001–2018 ($N = 40{,}937$)[1]

| | NHANES cycle | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Characteristic | 2001/2002 ($n = 4424$) | 2003/2004 ($n = 4206$) | 2005/2006 ($n = 4325$) | 2007/2008 ($n = 4932$) | 2009/2010 ($n = 5218$) | 2011/2012 ($n = 4433$) | 2013/2014 ($n = 4684$) | 2015/2016 ($n = 4353$) | 2017/2018 ($n = 4180$) | *P* value |
| Sex | | | | | | | | | | |
| Males | 2112 (48.5) | 2017 (48.0) | 2071 (48.0) | 2426 (47.0) | 2537 (48.1) | 2202 (48.9) | 2238 (48.6) | 2187 (48.0) | 2033 (48.3) | 0.92 |
| Females | 2312 (51.5) | 2189 (52.0) | 2254 (52.0) | 2506 (53.0) | 2681 (51.9) | 2231 (51.2) | 2446 (51.4) | 2348 (52.0) | 2147 (51.7) | |
| Age, mean ± SD, y | 44.9 ± 14.1 | 46.1 ± 14.0 | 46.4 ± 13.8 | 46.2 ± 14.7 | 46.8 ± 15.0 | 46.9 ± 13.7 | 47.2 ± 14.1 | 47.5 ± 13.8 | 48.1 ± 13.5 | <0.001 |
| Age group | | | | | | | | | | |
| 20–39 y | 1630 (40.9) | 1465 (39.1) | 1686 (38.2) | 1609 (37.8) | 1756 (36.9) | 1614 (36.7) | 1624 (36.1) | 1557 (36.5) | 1271 (36.3) | 0.054 |
| 40–59 y | 1394 (37.7) | 1192 (37.2) | 1328 (37.9) | 1570 (39.2) | 1751 (38.5) | 1458 (37.8) | 1601 (36.9) | 1510 (36.6) | 1324 (34.6) | |
| 60+ y | 1400 (21.4) | 1549 (23.7) | 1311 (23.9) | 1753 (23.0) | 1711 (24.5) | 1361 (25.5) | 1459 (27.0) | 1468 (26.9) | 1585 (29.1) | |
| Race/ethnicity | | | | | | | | | | |
| Non-Hispanic white | 2353 (72.8) | 2258 (72.8) | 2190 (72.9) | 2375 (70.8) | 2631 (70.4) | 1754 (67.5) | 2130 (66.8) | 1604 (65.9) | 1573 (63.6) | 0.32 |
| Non-Hispanic black | 814 (10.8) | 824 (11.4) | 980 (11.5) | 1036 (11.1) | 927 (11.0) | 1146 (11.1) | 930 (11.2) | 942 (10.5) | 951 (10.9) | |
| Hispanic | 1109 (12.5) | 964 (10.9) | 976 (10.3) | 1333 (12.9) | 1392 (12.7) | 847 (13.8) | 991 (13.9) | 1363 (14.4) | 892 (15.0) | |
| Other | 148 (3.9) | 160 (5.0) | 179 (5.3) | 188 (5.2) | 268 (5.9) | 686 (7.6) | 633 (8.1) | 626 (9.2) | 764 (10.6) | |
| Education level | | | | | | | | | | |
| <High school degree | 1312 (18.9) | 1210 (18.0) | 1156 (16.7) | 1492 (20.0) | 1413 (18.0) | 971 (15.3) | 916 (14.3) | 995 (13.0) | 752 (10.3) | <0.001 |
| High school degree/GED | 1041 (25.0) | 1033 (26.0) | 1045 (25.4) | 1209 (25.5) | 1196 (22.4) | 925 (19.7) | 1058 (22.2) | 1011 (21.0) | 1022 (28.5) | |
| Some college | 1164 (29.4) | 1162 (32.2) | 1245 (31.1) | 1288 (29.3) | 1504 (31.3) | 1373 (33.0) | 1486 (33.3) | 1366 (33.4) | 1392 (31.3) | |
| College degree or higher | 907 (26.7) | 801 (23.8) | 879 (26.7) | 943 (25.2) | 1105 (28.2) | 1164 (32.0) | 1224 (30.2) | 1163 (32.6) | 1014 (30.0) | |
| Income-to-poverty ratio | | | | | | | | | | |
| <130% | 1188 (21.3) | 1207 (21.4) | 1115 (17.4) | 1498 (21.4) | 1742 (22.2) | 1564 (25.1) | 1590 (25.1) | 1428 (21.0) | 1174 (20.7) | 0.35 |
| 130–349% | 1721 (35.2) | 1673 (37.5) | 1703 (37.5) | 1918 (34.1) | 1968 (35.8) | 1529 (33.8) | 1615 (34.3) | 1825 (36.8) | 1724 (35.6) | |
| ≥350% | 1515 (43.5) | 1326 (41.1) | 1507 (45.2) | 1516 (44.6) | 1508 (42.0) | 1340 (41.0) | 1479 (40.6) | 1282 (42.3) | 1282 (43.7) | |

[1]Values are presented as *n* (weighted %) unless otherwise indicated. GED, General Education Degree.

**TABLE 2** Trends in dietary intakes (percentage of total energy) of NOVA food groups and subgroups among of US adults (20 y and older) in each NHANES cycle, 2001–2018 ($N = 40,937$)[1]

| NOVA processing level and food group | NHANES cycle, mean percentage of total energy intake (95% CI) 2001/2002 ($n = 4744$) | 2003/2004 ($n = 4448$) | 2005/2006 ($n = 4520$) | 2007/2008 ($n = 5420$) | 2009/2010 ($n = 5762$) | 2011/2012 ($n = 4801$) | 2013/2014 ($n = 5047$) | 2015/2016 ($n = 5017$) | 2017/2018 ($n = 4742$) | Mean absolute change 2001–2018 | P-trend[2] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Minimally processed foods | 32.7 (32.0, 33.5) | 31.4 (30.6, 32.3) | 32.0 (31.2, 32.8) | 30.8 (29.7, 31.8) | 30.9 (29.6, 32.3) | 28.3 (27.2, 29.3) | 28.1 (27.0, 29.1) | 28.5 (27.6, 29.4) | 27.4 (26.1, 28.8) | –5.3 | <0.001 |
| Meat and poultry | 8.8 (8.3, 9.4) | 9.1 (8.5, 9.7) | 9.6 (9.2, 10.0) | 9.2 (8.8, 9.7) | 8.8 (8.2, 9.3) | 7.5 (7.0, 8.0) | 7.8 (7.3, 8.2) | 7.6 (7.1, 8.1) | 6.9 (6.4, 7.3) | –1.9 | 0.001 |
| Dairy | 4.4 (4.1, 4.7) | 3.9 (3.6, 4.2) | 3.9 (3.6, 4.3) | 3.8 (3.5, 4.1) | 4.0 (3.8, 4.2) | 3.4 (3.1, 3.7) | 3.1 (2.9, 3.3) | 3.1 (2.9, 3.3) | 3.0 (2.7, 3.3) | –1.4 | 0.001 |
| Other MPF | 4.0 (3.7, 4.3) | 3.6 (3.2, 4.0) | 3.5 (3.2, 3.8) | 2.5 (2.3, 2.7) | 2.6 (2.4, 2.7) | 2.3 (2.2, 2.5) | 2.3 (2.1, 2.5) | 2.5 (2.3, 2.8) | 2.6 (2.2, 3.0) | –1.4 | 0.001 |
| Roots | 2.1 (2.0. 2.3) | 2.0 (1.8, 2.1) | 2.0 (1.8, 2.2) | 2.0 (1.8, 2.1) | 1.9 (1.7, 2.1) | 1.8 (1.6, 1.9) | 1.6 (1.4, 1.7) | 1.9 (1.7, 2.1) | 1.8 (1.7, 2.0) | –0.3 | 0.005 |
| Legumes | 1.0 (0.8, 1.1) | 0.9 (0.7, 1.1) | 0.8 (0.7, 0.9) | 0.9 (0.8, 1.0) | 0.9 (0.8, 1.0) | 1.0 (0.9, 1.2) | 1.0 (0.9, 1.1) | 1.0 (0.8, 1.2) | 0.8 (0.6, 0.9) | –0.2 | 0.021 |
| Fruit/fruit juice | 4.5 (4.2, 4.9) | 4.2 (3.7, 4.8) | 4.4 (4.1, 4.7) | 4.6 (4.1, 5.0) | 4.9 (4.7, 5.2) | 4.5 (4.1, 4.9) | 4.1 (3.9, 4.4) | 4.1 (3.8, 4.4) | 3.9 (3.6, 4.2) | –0.6 | 0.26 |
| Pasta | 1.8 (1.4, 2.2) | 1.4 (1.1, 1.8) | 1.6 (1.5, 1.7) | 1.4 (1.2, 1.6) | 1.5 (1.3, 1.7) | 1.5 (1.2, 1.8) | 1.4 (1.3, 1.6) | 1.7 (1.4, 2.0) | 1.9 (1.5, 2.4) | 0.2 | 0.11 |
| Fish/seafood | 0.7 (0.7, 0.8) | 0.9 (0.7, 1.1) | 0.9 (0.8, 1.1) | 0.8 (0.7, 1.0) | 1.0 (0.8, 1.2) | 0.9 (0.7, 1.0) | 1.1 (0.9, 1.4) | 0.8 (0.6, 1.0) | 0.8 (0.6, 0.9) | 0.0 | 0.07 |
| Vegetables | 0.9 (0.8, 1.0) | 0.9 (0.9, 1.0) | 0.9 (0.8, 1.0) | 0.9 (0.8, 0.9) | 0.9 (0.8, 1.0) | 1.0 (0.9, 1.1) | 1.2 (1.1, 1.3) | 1.0 (1.0, 1.1) | 1.0 (0.8, 1.2) | 0.1 | 0.001 |
| Eggs | 1.6 (1.5, 1.7) | 1.7 (1.5, 1.8) | 1.5 (1.4, 1.6) | 1.7 (1.5, 1.8) | 1.5 (1.3, 1.6) | 1.5 (1.3, 1.6) | 1.6 (1.5, 1.8) | 1.8 (1.6, 2.0) | 1.8 (1.5, 2.1) | 0.2 | 0.007 |
| Grains | 3.0 (2.7, 3.2) | 2.8 (2.5, 3.1) | 2.8 (2.4, 3.2) | 3.0 (2.6, 3.5) | 3.0 (2.6,3.4) | 2.9 (2.6, 3.2) | 2.8 (2.4, 3.2) | 3.1 (2.7, 3.5) | 2.9 (2.4, 3.5) | 0.0 | 0.003 |
| Processed culinary ingredients | 3.9 (3.6, 4.3) | 3.6 (3.4, 3.8) | 4.3 (4.0, 4.5) | 3.9 (3.7, 4.1) | 3.9 (3.6, 4.1) | 4.6 (4.4, 4.8) | 4.7 (4.4, 4.9) | 5.3 (5.1, 5.5) | 5.4 (5.1, 5.7) | 1.4 | <0.001 |
| Sugar | 1.7 (1.5, 1.9) | 1.5 (1.4, 1.7) | 1.5 (1.4, 1.6) | 1.5 (1.4, 1.6) | 1.3 (1.2, 1.4) | 1.0 (0.9, 1.1) | 1.1 (1.0, 1.3) | 1.1 (1.0, 1.2) | 1.2 (1.1, 1.4) | –0.5 | 0.001 |
| Other CIs | 0.1 (0,1, 0.1) | 0.1 (0.1, 0.1) | 0.1 (0.1, 0.1) | 0.1 (0.1, 0.1) | 0.1 (0.1, 0.1) | 0.5 (0.4, 0.6) | 0.1 (0.0, 0.1) | 0.1 (0.0, 0.1) | 0.1 (0.0, 0.1) | 0.0 | 0.20 |
| Animal fats | 1.2 (1.0, 1.3) | 1.1 (1.0, 1.2) | 1.6 (1.5, 1.7) | 1.1 (1.0, 1.3) | 1.1 (1.0, 1.2) | 1.2 (1.1, 1.4) | 1.4 (1.3, 1.5) | 1.8 (1.6, 1.9) | 1.8 (1.6, 2.0) | 0.6 | 0.001 |
| Plant oils | 1.0 (0.9, 1.1) | 0.8 (0.7, 1.0) | 1.1 (1.0, 1.2) | 1.2 (1.1, 1.3) | 1.4 (1.2, 1.5) | 1.9 (1.7, 2.1) | 2.1 (1.9, 2.2) | 2.3 (2.2, 2.5) | 2.3 (2.1, 2.5) | 1.3 | 0.001 |
| Processed foods | 9.8 (9.1, 10.4) | 10.2 (9.6, 10.6) | 10.5 (9.7, 11.2) | 10.0 (9.1, 10.8) | 10.0 (9.5, 10.4) | 10.4 (9.9, 11.0) | 10.7 (10.2, 11.2) | 10.9 (10.3, 11.6) | 10.2 (9.4, 11.0) | 0.5 | 0.052 |
| Canned/pickled F&V | 1.0 (0.9, 1.1) | 0.9 (0.8, 1.1) | 0.9 (0.8, 0.9) | 0.8 (0.7, 0.9) | 0.8 (0.7, 0.9) | 0.7 (0.6, 0.7) | 0.6 (0.5, 0.7) | 0.6 (0.6, 0.7) | 0.6 (0.5, 0.7) | –0.3 | 0.001 |
| Canned/smoked meat and fish | 1.2 (1.0, 1.3) | 1.1 (1.0, 1.3) | 1.1 (1.0, 1.2) | 1.1 (1.0, 1.2) | 1.1 (0.9, 1.2) | 0.9 (0.8, 1.0) | 0.9 (0.8, 1.0) | 1.0 (0.9, 1.1) | 1.0 (0.8, 1.2) | –0.2 | 0.013 |
| Cheese | 3.2 (2.9, 3.4) | 3.3 (2.8, 3.8) | 3.4 (3.2, 3.6) | 3.2 (2.8, 3.6) | 3.0 (2.7, 3.2) | 3.1 (2.9, 3.3) | 3.3 (3.0, 3.7) | 3.5 (3.2, 3.8) | 3.5 (3.2, 3.9) | 0.4 | 0.11 |
| Other processed foods | 4.5 (4.0, 5.0) | 4.9 (4.5, 5.3) | 5.1 (4.5, 5.6) | 4.8 (4.3, 5.4) | 5.1 (4.7, 5.5) | 5.8 (5.3, 6.2) | 6.0 (5.5, 6.4) | 5.8 (5.3, 6.4) | 5.1 (4.6, 5.5) | 0.6 | 0.003 |
| Ultra-processed foods | 53.5 (52.5, 54.6) | 54.8 (53.7, 55.9) | 53.2 (52.0, 54.5) | 55.3 (53.7, 57.0) | 55.2 (53.9, 56.6) | 56.6 (55.5, 57.8) | 56.5 (55.3, 57.7) | 55.3 (54.4, 56.1) | 57.0 (55.0, 58.9) | 3.4 | <0.001 |
| Sodas | 5.6 (5.1, 6.2) | 5.5 (5.0, 6.0) | 4.3 (4.0, 4.7) | 4.4 (3.7, 5.1) | 3.8 (3.4, 4.1) | 3.8 (3.4, 4.1) | 4.1 (3.7, 4.4) | 3.6 (3.3, 4.0) | 3.5 (3.0, 4.1) | –2.1 | 0.001 |
| Other UPF | 5.5 (5.2, 5.8) | 5.9 (5.6, 6.3) | 4.7 (4.4, 5.1) | 4.7 (4.5, 4.9) | 4.5 (4.4, 4.7) | 3.6 (3.2, 4.0) | 3.2 (2.9, 3.6) | 3.4 (3.0, 3.7) | 3.9 (3.6, 4.2) | –1.5 | 0.001 |
| Breakfast cereals | 2.6 (2.3, 2.9) | 2.2 (2.0, 2.4) | 2.3 (2.1, 2.6) | 2.5 (2.2, 2.8) | 2.6 (2.3, 2.8) | 2.4 (2.1, 2.7) | 2.1 (1.9, 2.2) | 2.0 (1.8, 2.3) | 1.8 (1.6, 2.0) | –0.8 | 0.001 |
| Bread | 10.9 (10.6, 11.2) | 10.8 (10.4, 11.2) | 10.8 (10.4, 11.1) | 10.7 (10.2, 11.2) | 10.6 (10.1, 11.2) | 10.6 (10.1, 11.0) | 10.4 (10.1, 10.8) | 9.8 (9.2, (10.3) | 10.0 (9.4, 10.6) | –0.9 | 0.003 |
| Noncarbonated sweet drinks | 2.7 (2.4, 3.1) | 2.6 (2.2, 2.9) | 2.5 (2.3, 2.8) | 2.8 (2.5, 3.1) | 2.8 (2.6, 3.1) | 3.0 (2.6, 3.3) | 2.2 (2.0, 2.5) | 2.2 (1.9, 2.4) | 2.4 (2.1, 2.7) | –0.3 | 0.004 |
| Ice cream | 2.1 (1.8, 2.4) | 2.2 (1.9, 2.4) | 2.2 (1.9, 2.5) | 2.1 (1.9, 2.2) | 2.2 (2.0, 2.4) | 1.9 (1.5, 2.3) | 1.9 (1.7, 2.1) | 1.7 (1.5, 2.0) | 1.7 (1.4, 1.9) | –0.4 | 0.002 |
| Ultra-processed potato products | 1.6 (1.4, 1.9) | 1.5 (1.1, 1.9) | 1.5 (1.2, 1.8) | 1.4 (1.3, 1.5) | 1.7 (1.6, 1.8) | 1.6 (1.3, 1.8) | 1.7 (1.5, 1.9) | 1.3 (1.1, 1.5) | 1.5 (1.3, 1.8) | –0.1 | 0.052 |
| Dairy-based drinks | 1.2 (1.0, 1.3) | 1.2 (1.0, 1.3) | 1.4 (1.2, 1.6) | 1.2 (1.0, 1.4) | 1.4 (1.2, 1.6) | 1.4 (1.2, 1.6) | 1.4 (1.3, 1.6) | 1.3 (1,1, 1.5) | 1.0 (0.8, 1.3) | –0.1 | 0.26 |
| Salty snack food | 4.2 (3.9, 4.5) | 4.1 (3.8, 4.3) | 4.1 (3.8, 4.5) | 4.3 (3.9, 4.7) | 4.2 (3.9, 4.4) | 4.3 (4.0, 4.7) | 4.3 (3.9, 4.6) | 4.1 (3.8, 4.4) | 4.3 (4.0, 4.6) | 0.1 | 0.20 |
| Sauces | 3.4 (3.1, 3.6) | 3.3 (3.1, 3.6) | 3.5 (3.2, 3.8) | 3.2 (3.0, 3.4) | 2.9 (2.7, 3.0) | 2.9 (2.6, 3.2) | 3.0 (2.8, 3.2) | 3.2 (2.9, 3.5) | 3.5 (3.2, 3.8) | 0.1 | 0.051 |
| Sweet snack foods | 2.4 (2.1, 2.6) | 2.5 (2.2, 2.7) | 2.5 (2.1, 2.8) | 2.8 (2.4, 3.3) | 2.4 (2.2, 2.6) | 2.4 (2.1, 2.7) | 2.7 (2.4, 3.0) | 2.5 (2.2, 2.7) | 2.7 (2.5, 3.0) | 0.4 | 0.14 |
| Instant/canned soups | 0.8 (0.7, 0.9) | 0.6 (0.6, 0.7) | 0.7 (0.6, 0.9) | 0.7 (0.6, 0.8) | 0.7 (0.6, 0.9) | 0.7 (0.6, 0.8) | 0.8 (0.7, 0.9) | 0.9 (0.7, 1.1) | 1.0 (0.7, 1.3) | 0.2 | 0.003 |
| Cakes, cookies, and pies | 4.5 (4.2, 4.9) | 4.9 (4.5, 5.4) | 4.8 (4.4, 5.2) | 4.2 (3.8, 4.6) | 4.2 (3.9, 4.4) | 5.1 (4.6, 5.5) | 5.3 (5.0, 5.6) | 5.2 (4.8, 5.5) | 5.1 (4.6, 5.6) | 0.5 | 0.002 |
| Confectionary | 0.7 (0.6, 0.8) | 0.8 (0.7, 0.9) | 0.8 (0.7, 0.9) | 0.9 (0.8, 1.1) | 0.9 (0.8, 0.9) | 1.1 (1.0, 1.3) | 1.1 (1.0, 1.2) | 1.1 (1.0, 1.2) | 1.4 (1.1, 1.7) | 0.7 | 0.001 |
| Reconstituted meat and fish products | 4.2 (3.8, 4.6) | 4.1 (3.7, 4.6) | 3.4 (3.0, 3.8) | 3.6 (3.3, 3.8) | 3.0 (2.6, 3.4) | 2.8 (2.5, 3.1) | 3.7 (3.5, 3.9) | 4.5 (4.1, 4.8) | 5.4 (5.0, 5.9) | 1.2 | 0.004 |
| Frozen/shelf-stable meals | 1.1 (0.8, 1.4) | 2.1 (1.8, 2.4) | 2.0 (1.7, 2.3) | 2.5 (2.2, 2.8) | 2.9 (2.6, 3.2) | 4.1 (3.7, 4.5) | 3.1 (2.4, 3.8) | 2.7 (2.4, 3.1) | 2.7 (2.1, 3.2) | 1.6 | 0.001 |
| Sandwiches and hamburgers | 0.1 (0.0, 0.1) | 0.1 (0.0, 0.2) | 1.1 (0.9, 1.2) | 0.8 (0.7, 1.0) | 1.5 (1.1, 1.8) | 2.0 (1.7, 2.3) | 2.3 (2.0, 2.6) | 2.7 (2.3, 3.1) | 1.8 (1.4, 2.3) | 1.8 | 0.001 |
| Frozen pizzas[3] | − 0.1 (−0.2, −0.1) | 0.3 (0.1, 0.6) | 0.5 (0.3, 0.7) | 2.4 (2.1, 2.7) | 3.1 (2.7, 3.5) | 3.1 (2.5, 3.7) | 3.2 (2.7, 3.8) | 3.1 (2.6, 3.5) | 3.1 (2.7, 3.6) | 3.2 | 0.001 |

[1]Values are presented as multivariable adjusted, survey-weighted means (95% CI). Means are adjusted for age (continuous), sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanic, other race), education level (less than high school, high school degree/General Education Degree, some college, college graduate), and income-to-poverty ratio (<130%, 130–349%, ≥350%). CI, processed culinary ingredient; F&V, fruit and vegetables; MPF, minimally processed food; UPF, ultra-processed food.

[2]*P*-trend values presented for NOVA subgroups are adjusted for multiple comparisons by calculation of false discovery rate *q* values.

[3]Food codes, portions, and weights of pizza were revised for Food and Nutrient Database for Dietary Studies 4.1 (corresponding to NHANES 2007–2008), for which values before and after 2007–2008 may not be comparable.

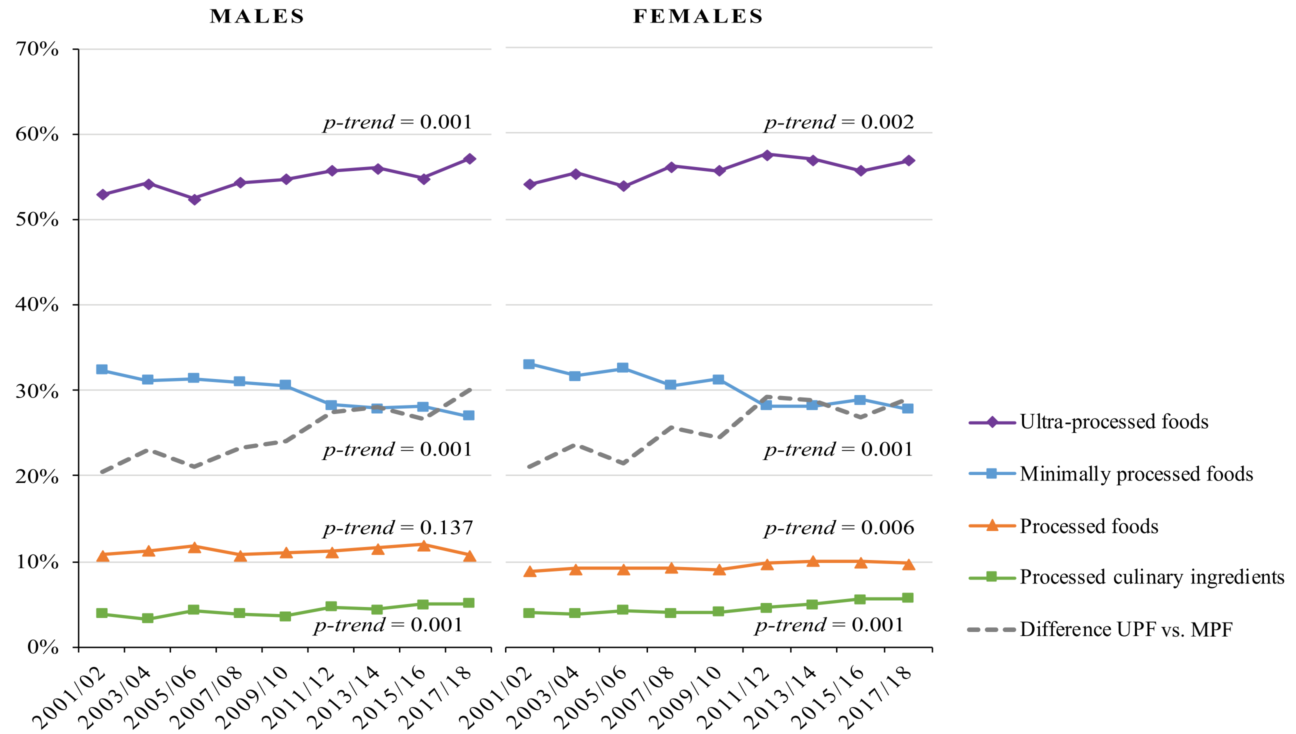


**FIGURE 2** Trends in consumption (percentage of total energy) of NOVA food groups among males and females, NHANES 2001–2018 ($N$ = 40,937). Means are survey-weighted and adjusted for age, race/ethnicity, education, and income-to-poverty ratio. $P$-trend values are adjusted for multiple comparisons by calculation of false discovery rate $q$ values. MPF, minimally processed food; UPF, ultra-processed food.

Across all education levels, mean intake of ultra-processed foods ($P$-trend $< 0.05$, $P$-interaction education × year = 0.24) and processed culinary ingredients increased ($P$-trend = 0.001, $P$-interaction education × year = 0.07), whereas mean intake of minimally processed foods decreased ($P$-trend = 0.001, $P$-interaction education × year = 0.11) from 2001–2002 to 2017–2018. Throughout the study period, college graduates consumed more minimally processed foods and less ultra-processed foods than adults with lower levels of education.

From 2001 to 2018, mean intake of minimally processed foods decreased ($P$-trend = 0.001; $P$-interaction income × year = 0.27), whereas the intake of ultra-processed foods ($P$-trend $< 0.05$; $P$-interaction income × year = 0.26) and processed culinary ingredients increased ($P$-trend $< 0.001$; $P$-interaction income × year = 0.23) among adults of all income levels. Meanwhile, the intake of processed foods increased among individuals with a household income of <130% (+1.6 %kcal; $P$-trend = 0.001) and 130–349% of the federal poverty threshold only (+0.7 %kcal; $P$ = 0.023 $P$-interaction income × year = 0.0313).

## Discussion

The current findings contribute to our understanding of the consumption of industrially processed foods in the United States and how consumption differs between population groups with established disparities in diet quality. Controlling for changes in population characteristics, the consumption of ultra-processed foods increased among US adults from 2001 to 2018. The largest increases were observed for ready-to-eat/heat meals, whereas the intake of several high sugar- and grain-based foods and drinks decreased. Meanwhile, the consumption of minimally processed foods decreased across all population groups, primarily due to reduced consumption of meat and dairy.

The trend toward considerably increased consumption of ultra-processed foods among older adults (aged 60+ y) is notable, as previous studies have observed an inverse association between ultra-processed food consumption and age (14) and trends toward reduced intake of ultra-processed foods with advancing age (24). Nevertheless, other studies have also noted unfavorable dietary shifts among older adults in recent years. For example, the prevalence of heavy sugar-sweetened beverage consumption (500+ kcal/d) increased significantly in the 60+-y age group from 2003 to 2016 but remained unchanged or decreased in all other age groups (25). Furthermore, diet quality, defined by the Healthy Eating Index 2015, did not increase to the same extent among older adults as among younger adults from 1999 to 2016 (11). An increased consumption of ultra-processed foods and decreased consumption of minimally processed foods among older adults in recent years may reflect the food environment during their childhood and adolescence. Adults aged 60 y and above in 2010 were born before 1950, whereas those aged 60 y in 2017–2018 were born in the 1960s. This generation of older adults grew up during a time when ultra-processed foods were increasingly available and marketed in the United States, which may have influenced their preferences and dietary habits.

In the current study, Hispanics and college graduates consumed significantly less ultra-processed foods and more

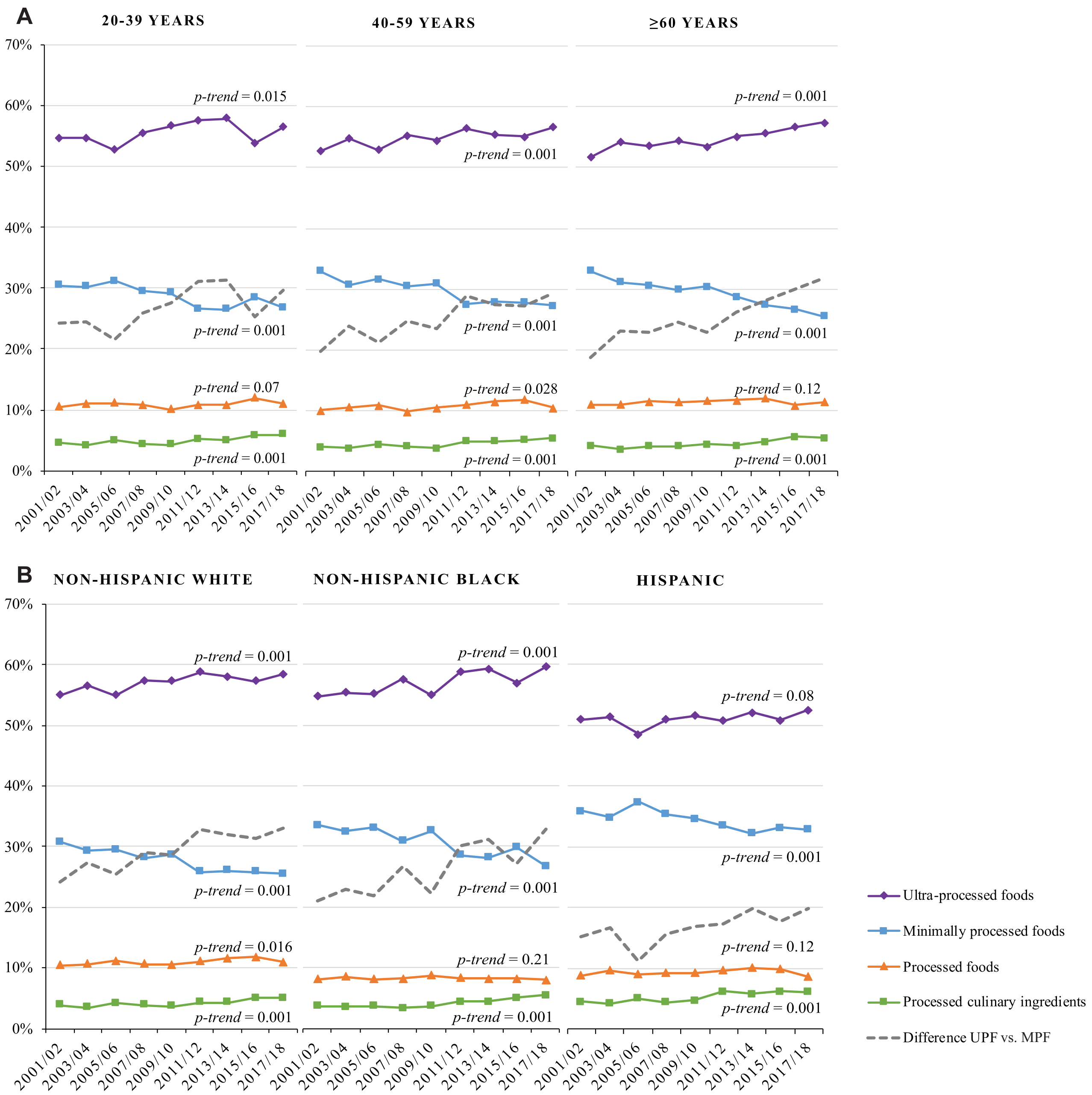


**FIGURE 3** Trends in consumption (percentage of total energy) of NOVA food groups stratified by (A) age and (B) race/ethnicity, NHANES 2001–2018 ($N = 40{,}937$). Means are survey-weighted and adjusted for age (race/ethnicity-stratified analyses only), sex, race/ethnicity (age-stratified analyses only), education, and income-to-poverty ratio. *P*-trend values are adjusted for multiple comparisons by calculation of false discovery rate *q* values. MPF, minimally processed food; UPF, ultra-processed food.

minimally processed foods than other racial and educational groups, respectively, at all time points. It is well established that Hispanics and highly educated adults tend to have higher diet quality than other sociodemographic groups (26). Given the inverse association between ultra-processed foods and diet quality (27), the higher diet quality of Hispanics and highly educated individuals may partly be driven by lower intakes of ultra-processed food.

It is well documented that energy-dense foods composed of refined grains, added sugars, or fats (i.e., ultra-processed foods) tend to be cheaper per calorie than nutrient-dense minimally processed foods, such as fruit, vegetables, meat, and fish and are often selected by lower-income groups (28). Nevertheless, ultra-processed food consumption increased among all income groups from 2001 to 2018. It is possible that the large market segment of "premium" ultra-processed foods that are typically marketed as being of higher quality, healthier, or having functional properties (e.g., added fiber, probiotics, and $\omega$-3 fatty acids) and tend to be more expensive than traditional ultra-processed foods are driving the observed increases in consumption among

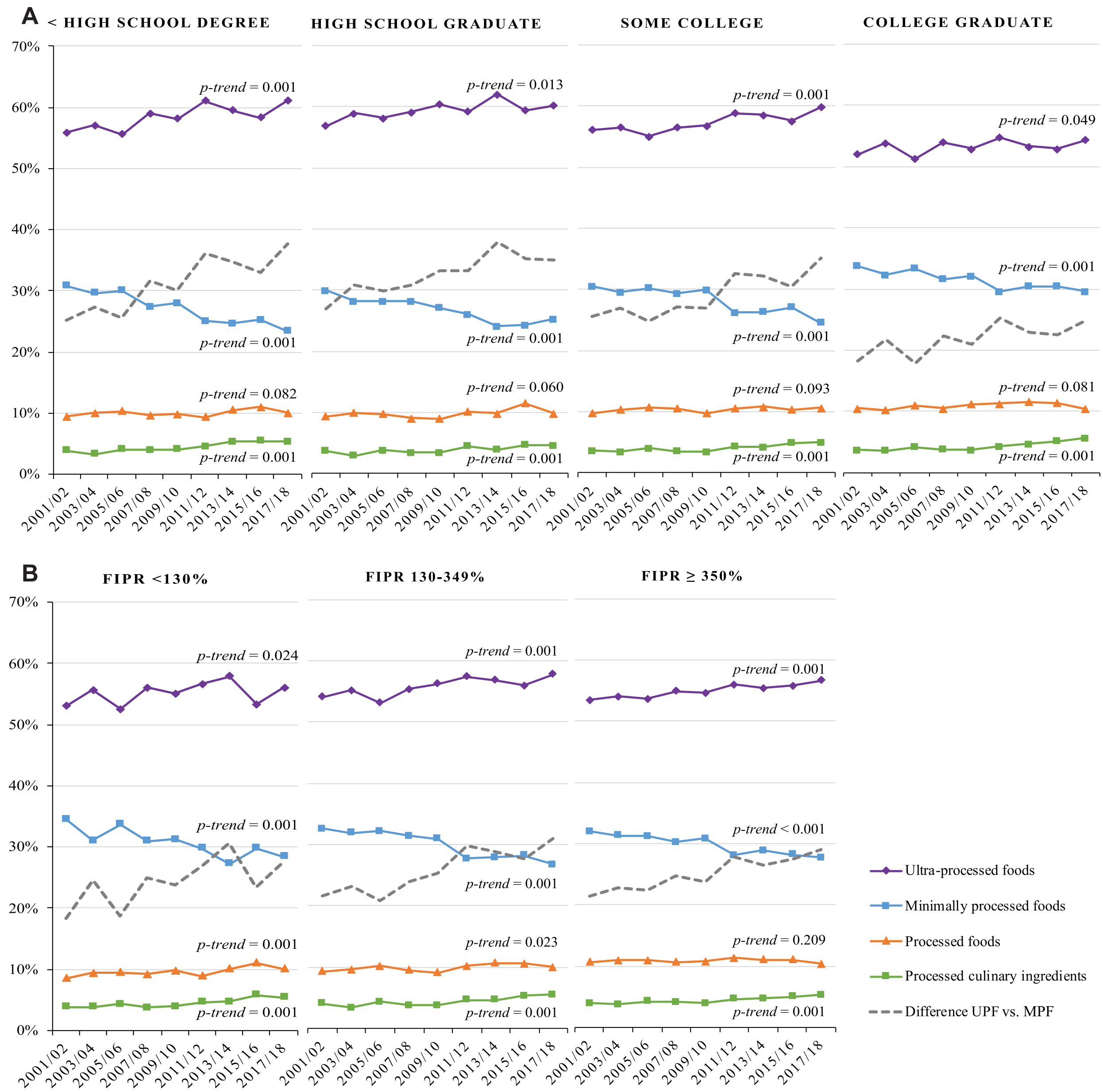


**FIGURE 4** Trends in consumption (percentage of total energy) of NOVA food groups stratified by (A) education and (B) income level (defined as family income to poverty ratio), NHANES 2001–2018 ($N = 40{,}937$). Means are survey-weighted and adjusted for age, sex, race/ethnicity, education (income-stratified analyses only), and income-to-poverty ratio (education level–stratified analyses only). *P*-trend values are adjusted for multiple comparisons by calculation of false discovery rate *q* values. FIPR, family income to poverty ratio; MPF, minimally processed food; UPF, ultra-processed food.

medium- and higher-income individuals (29). However, the granularity of the dietary data is insufficient to distinguish “premium” products from other ultra-processed foods and test this hypothesis.

The continued high and increasing consumption of ultra-processed foods in the 21st century may be a key driver of the US obesity epidemic. In the United States, mean BMI (in kg/m$^2$) increased from 27.8 to 29.1 in males and from 28.2 to 29.6 in females between 1999 and 2016 (30). Meanwhile, the prevalence of obesity increased from 27.5% to 43.0% among males and from 33.4 to 41.9% among females from 1999 to 2018 (31). These changes occurred in parallel to the increasing consumption of ultra-processed foods, despite improving macronutrient composition of adults’ diets over the same period (11). Accumulating epidemiologic and experimental evidence supports that greater intake of ultra-processed foods is associated with increased risk of obesity (32–35). In the French NutriNet-Santé cohort, an increase of 10% of ultra-processed food in the diet was associated with an 11% and 9% increased risk of incident overweight and obesity, respectively, during a median follow-up of 4.1 y (34). Furthermore, a randomized controlled crossover trial demonstrated that participants gained weight when given an ad libitum ultra-processed diet and lost weight when they received an energy- and macronutrient-matched minimally processed diet (35). Epidemiologic studies also link ultra-processed foods to chronic diseases such as cardiovascular disease, cancer, and hypertension through pathways beyond nutrient composition, energy intake, and excess adiposity (36–39). Hypothesized mechanisms include the poor nutritional quality, novel physical structure, and chemical composition of ultra-processed foods (40).

The current findings should be interpreted in light of the study's limitations. First, ultra-processed food intake may be underestimated as individuals tend to underreport foods considered unhealthy, including ultra-processed foods such as confectionary, pastries, and French fries, to a larger extent than minimally processed foods such as fruit and vegetables (41). Second, dietary assessment by 24-h recall has known issues of measurement error. Nevertheless, the AMPM is a validated method for dietary data collection that has been shown to reduce bias in dietary data collection (18, 19). Although a single dietary recall may not be representative of an individual's usual diet, evidence suggests that it provides a representative estimate of average intake at the group level (42). Finally, foods may have been misclassified as it was not always possible to determine NOVA group with certainty due to insufficient information. In case of uncertainty, we used a conservative approach and assigned the lower level of processing.

Notable strengths of the current study include the rigorous design and methodology of NHANES and 18 y of consecutive data collected from a large, nationally representative sample. As a result, the current findings have high external validity. Furthermore, processing level was determined according to the objective and standardized criteria of NOVA. By disaggregating dishes into their constituents, we were able to calculate more precise estimates of intakes of each NOVA group and reduced the risk of misclassification.

### Conclusion and public health implications

The current study uniquely determines trends in diet processing level over 18 y across sociodemographic groups in a nationally representative sample of US adults. Our findings highlight the high consumption of ultra-processed foods in all parts of the population and demonstrate that intake has continuously increased in the majority of the population, regardless of income level over the past 2 decades. Processing level constitutes a novel dimension of diet quality that captures qualitative aspects of foods and diets that tend to be overlooked in traditional nutrient-centric metrics. The United States currently has no policies related to ultra-processed foods as a group, and processing level is not considered in the Dietary Guidelines for Americans (43). Given the increasing consumption of ultra-processed foods in the United States and accumulating evidence linking these products to chronic diseases, we recommend that policies should be implemented to reduce their consumption, as has been done in several other countries. For example, Brazil and Israel have developed food-based dietary guidelines dissuading ultra-processed food consumption, and Chile has implemented strict food-marketing and front-of-package labeling legislation (44–46). To successfully reduce the consumption of ultra-processed foods in the US population, we must also increase the availability, accessibility, and affordability of nutritious minimally processed foods, especially among disadvantaged populations.

The authors' contributions were as follows—FJ and VWC: developed the overall research plan and designed the statistical analyses within the existing data set; FJ: performed the statistical analyses and took the lead in writing the manuscript; EM-S and FJ: classified the dietary data into the primary outcome variables; EM-S: aided in the interpretation of the data and revised the manuscript for critical intellectual content; NP: provided expertise regarding statistical analyses as it pertains to nutritional epidemiology and revised the manuscript for important intellectual content; CAM: developed and defined the NOVA classification that was used in the present study and revised the article for critical intellectual content; VWC: participated in the analysis and interpretation of data, revised the manuscript for important intellectual content, and oversaw the entire study; and all authors: approved the final manuscript and take full responsibility for the final content.

Author disclosures: The authors report no conflicts of interest.

## Data Availability

Data described in the manuscript, code book, and analytic code will be made available upon request pending application and approval.

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