

Trends in Dietary Carbohydrate, Protein, and Fat Intake and Diet Quality Among US Adults, 1999-2016

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IMPORTANCE Changes in the economy, nutrition policies, and food processing methods can affect dietary macronutrient intake and diet quality. It is essential to evaluate trends in dietary intake, food sources, and diet quality to inform policy makers.

OBJECTIVE To investigate trends in dietary macronutrient intake, food sources, and diet quality among US adults.

DESIGN, SETTING, AND PARTICIPANTS Serial cross-sectional analysis of the US nationally representative 24-hour dietary recall data from 9 National Health and Nutrition Examination Survey cycles (1999-2016) among adults aged 20 years or older.

EXPOSURE Survey cycle.

MAIN OUTCOMES AND MEASURES Dietary intake of macronutrients and their subtypes, food sources, and the Healthy Eating Index 2015 (range, 0-100; higher scores indicate better diet quality; a minimal clinically important difference has not been defined).

RESULTS There were 43 996 respondents (weighted mean age, 46.9 years; 51.9% women). From 1999 to 2016, the estimated energy from total carbohydrates declined from 52.5% to 50.5% (difference, -2.02%; 95% CI, -2.41% to -1.63%), whereas that of total protein and total fat increased from 15.5% to 16.4% (difference, 0.82%; 95% CI, 0.67%-0.97%) and from 32.0% to 33.2% (difference, 1.20%; 95% CI, 0.84%-1.55%), respectively (all $P < .001$ for trend). Estimated energy from low-quality carbohydrates decreased by 3.25% (95% CI, 2.74%-3.75%; $P < .001$ for trend) from 45.1% to 41.8%. Increases were observed in estimated energy from high-quality carbohydrates (by 1.23% [95% CI, 0.84%-1.61%] from 7.42% to 8.65%), plant protein (by 0.38% [95% CI, 0.28%-0.49%] from 5.38% to 5.76%), saturated fatty acids (by 0.36% [95% CI, 0.20%-0.51%] from 11.5% to 11.9%), and polyunsaturated fatty acids (by 0.65% [95% CI, 0.56%-0.74%] from 7.58% to 8.23%) (all $P < .001$ for trend). The estimated overall Healthy Eating Index 2015 increased from 55.7 to 57.7 (difference, 2.01; 95% CI, 0.86-3.16; $P < .001$ for trend). Trends in high- and low-quality carbohydrates primarily reflected higher estimated energy from whole grains (0.65%) and reduced estimated energy from added sugars (-2.00%), respectively. Trends in plant protein were predominantly due to higher estimated intake of whole grains (0.12%) and nuts (0.09%).

CONCLUSIONS AND RELEVANCE From 1999 to 2016, US adults experienced a significant decrease in percentage of energy intake from low-quality carbohydrates and significant increases in percentage of energy intake from high-quality carbohydrates, plant protein, and polyunsaturated fat. Despite improvements in macronutrient composition and diet quality, continued high intake of low-quality carbohydrates and saturated fat remained.

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Unhealthy diet is a major risk factor for noncommunicable diseases globally, including type 2 diabetes mellitus, cardiovascular disease, and certain types of cancer.¹⁻³ In the United States, poor diet was estimated to be the leading cause of death and the third leading cause of disability-adjusted life-year loss.⁴ Consequently, evaluation of overall population trends in diet is important to identifying challenges and opportunities for improving the diet of all US adults.

The calorie demands of the human body are mainly supplied by 3 dietary macronutrients: carbohydrate, fat, and protein.⁵ As within-person variation in energy intake is small over extended periods, increases in consumption of one macronutrient often leads to decreases in another. In addition to the quantity, the food sources and types of macronutrients are also important in understanding their associations with disease risks.⁶⁻¹⁰ Changes in the economy, nutrition-related policies, and food processing methods can affect the macronutrient composition and diet quality at the population level. However, evidence is still limited in trends of macronutrient composition, their subtypes, and food sources.¹¹⁻¹³

This report describes data from 9 consecutive cycles of the National Health and Nutrition Examination Survey (NHANES) to examine trends in dietary macronutrients intake, major food sources of carbohydrate and protein, and overall dietary quality among US adults from 1999 to 2016.

Methods

Study Design and Population

The NHANES study protocol was approved by the research ethics review board of the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention, and all participants provided written informed consent. NHANES has been a nationally representative cross-sectional study since 1999, conducted by the NCHS, that obtains information on health and nutritional status of the noninstitutionalized civilian population in the United States.¹⁴ The study design, protocol, and data collection methods have been reported.¹⁵ Information on race/ethnicity was self-reported by NHANES participants via standardized questionnaires according to categories provided by the NCHS (non-Hispanic white, non-Hispanic black, Mexican American, other Hispanic, or other). Mexican American and other Hispanic groups were combined to create the Hispanic group. This information was collected to report changes in macronutrient intake and diet quality by race/ethnicity.

For these analyses, the study population included adults aged 20 years or older who completed at least 1 valid dietary recall during the 9 cycles of NHANES from 1999-2000 through 2015-2016. A diet recall was considered valid when all relevant variables associated with the diet recall contained a value.¹⁶

Assessment of Food Groups and Nutrients

In NHANES, diet was assessed using 24-hour recalls. From 1999 to 2002, one 24-hour dietary recall was conducted in person

Key Points

Question What were the trends in carbohydrate, fat, and protein intake among US adults from 1999 to 2016?

Findings In this nationally representative serial cross-sectional study that included 43 996 adults, there were decreases in low-quality carbohydrates (primarily added sugar) and increases in high-quality carbohydrates (primarily whole grains), plant protein (primarily whole grains and nuts), and polyunsaturated fat. However, 42% of energy intake was still derived from low-quality carbohydrates and the intake of saturated fat remained above 10% of energy.

Meaning The macronutrient composition of diet among US adults has improved, but continued high intake of low-quality carbohydrates and saturated fat remain.

in the NHANES Mobile Examination Center. Beginning in 2003, a second 24-hour recall was administered by a telephone interview approximately 3 to 10 days after the first recall.¹⁷ The 4-step “multiple-pass method” was used between 1999 and 2001, and the 5-step “automated multiple-pass method” was introduced beginning in 2002. The multiple-pass method is designed to enhance complete and accurate food recall and reduce respondent burden. The multiple-pass method included collecting a self-reported food list, probing for foods forgotten, collecting details of foods, and final probing for any other foods.¹⁸ A standard set of measuring guides (eg, rectangular grid, measuring cups and spoons, and bowls) were used to help the respondent report the volume and dimensions of food items consumed.¹⁹ All foods and beverages consumed during the previous 24 hours (midnight to midnight) were recorded. The dietary sampling weights were used to account for the complex study design (eg, oversampling of minorities), missing dietary data, and poststratification.²⁰

To assess intake of major foods groups, the same definitions were used for the same food groups in the US Department of Agriculture (USDA) Food Patterns Equivalents Database and MyPyramid Equivalents Database across different survey cycles. Nutrients were estimated based on cycle-specific versions of the USDA Food and Nutrition Database for Dietary Studies. A multiple-step process was developed based on methods previously used to estimate protein sources in NHANES.²¹ The process included estimation for foods that contained ingredients totally assigned to specific sources, estimation for the other foods, and summing the amount of protein and carbohydrate from each source in all foods (see eAppendix in the Supplement). Food sources of fat were not investigated because they are similar to protein food sources, and existing evidence on fat is mostly based on types of fatty acids rather than on particular food sources.⁶

Outcomes

The primary outcomes were energy intake from the major macronutrients and their subtypes, food sources of carbohydrate and protein, and overall diet quality as assessed by the Healthy Eating Index (HEI) 2015. The subtypes of macronutrients included high- and low-quality carbohydrates, animal and plant

protein, saturated fatty acids, monounsaturated fatty acids, and polyunsaturated fatty acids. Food sources constituting these subtypes are shown in eTable 1 in the Supplement.

Diet quality was assessed using the HEI-2015, which measures adherence to key recommendations in the 2015-2020 Dietary Guidelines for Americans.²² The foods and nutrients were represented on a density basis as amounts per 1000 kcal. The 9 adequacy components included 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 included refined grains, sodium, percentage of energy from added sugars, and percentage of energy from saturated fatty acids. The scoring method is described in eTable 2 in the Supplement. The total HEI-2015 score ranges from 0 (nonadherence) to 100 (perfect adherence). No minimal clinically important difference has been defined for the HEI-2015.

Secondary outcomes were trends in intakes of macronutrients and diet quality by major population subgroups, including age, sex, race/ethnicity, education, and income level.

Statistical Analysis

All analyses incorporated the dietary sample weights, stratification, and clustering of the complex sampling design to ensure nationally representative estimates. To correct for measurement error, the absolute intakes of nutrients in grams per day were adjusted for total energy intake to 2000 kcal/d using the residual method to minimize measurement error in dietary estimates.²³ Additionally, the National Cancer Institute (NCI) method was applied to estimate the usual intake and distribution for all nutrients and food groups (eAppendix in the Supplement). The NCI method is preferred for estimating usual intake distribution from 24-hour diet recalls.²⁴ Percentage of energy of a nutrient was computed as proportion of energy from the nutrient over total energy intake. For instance, for total carbohydrate, percentage of energy = (total carbohydrate [g] × 4 [kcal/g])/total energy intake (kcal) × 100. Total energy intake was estimated as the sum of energy from protein, carbohydrates, and fat. Weighted means and 95% confidence intervals were estimated for dietary macronutrients and the HEI-2015 by cycle. General linear regression was used to estimate trends by treating 2-year survey cycle as a continuous variable. Absolute differences in estimated means were calculated between 1999-2000 and 2015-2016 cycles. Because NHANES started collecting 2 dietary recalls with the 2003-2004 cycle, in sensitivity analyses, the absolute difference was calculated between the 2003-2004 and 2015-2016 cycles. Similar analyses were conducted using the estimates of energy-adjusted absolute intake in grams per day among the overall population. To evaluate potential differences in trends by population subgroups (age, sex, race/ethnicity, education, and income), a survey-weighted Wald *F* statistic was used to test for an interaction between 2-year survey cycle and demographic subgroups, and statistical significance was set at *P* = .001 (.05/5 [subgroups] × 9 [nutrients and diet quality]). To determine the degree to which observed trends were due to demographic shifts, additional analyses were performed

adjusting for sociodemographic characteristics. Participants with missing data on education and income were excluded in the corresponding subgroup analyses and multivariable analysis. All data were analyzed using SAS version 9.4 (SAS Institute Inc), and statistical significance was set at a 2-tailed *P* < .05 for all primary analyses. Because of the potential for type I error due to multiple comparisons, findings for the primary and secondary outcomes not corrected for multiple comparisons should be interpreted as exploratory.

Results

Participant Characteristics

Between 1999 and 2016, 88.9% (44 013/49 512) of the NHANES respondents aged 20 years or older provided a single dietary recall. Of these, 70.2% (30 894/44 013) provided a second recall. Participants with invalid diet recalls (*n* = 17) were excluded.

A total of 43 996 US adults (weighted mean age, 46.9 years [SE, 0.19 years]; *n* = 22 796 [51.9%] women) were included in these analyses. From 1999 to 2016, the proportion of older adults (aged ≥65 years) increased from 18.0% to 21.1%, while the proportion of younger adults (aged 20-34 years) decreased from 30.0% to 27.8% (Table 1). The proportion who were non-Hispanic white declined from 69.8% to 64.4%, whereas the percentage of other races/ethnicities increased from 4.6% to 9.6%. The proportion of respondents with at least some college education increased from 49.1% to 65.3%.

Total and Subtypes of Carbohydrate, Protein, and Fat Intake

From 1999 to 2016, the estimated percentage of energy intake from total carbohydrates declined from 52.5% to 50.5% (difference, -2.02%; 95% CI, -2.41% to -1.63%; *P* < .001 for trend) (Figure 1 and eTable 3 in the Supplement). The estimated percentage of energy from high-quality carbohydrates increased from 7.42% to 8.65% (difference, 1.23%; 95% CI, 0.84%-1.61%; *P* < .001 for trend), whereas that from low-quality carbohydrates decreased from 45.1% to 41.8% (difference, -3.25%; 95% CI, -3.75% to -2.74%; *P* < .001 for trend) (Figure 2 and eTable 3). The estimated percentage of energy from total protein increased from 15.5% to 16.4% (difference, 0.82%; 95% CI, 0.67%-0.97%; *P* < .001 for trend) and that from total fat increased from 32.0% to 33.2% (difference, 1.20%; 95% CI, 0.84%-1.55%; *P* < .001 for trend). The increases in the estimated total protein energy intake were associated with increases in estimated intake from both animal protein (from 10.2% to 10.6%; difference, 0.44%; 95% CI, 0.33%-0.54; *P* < .001 for trend) and plant protein (from 5.38% to 5.76%; difference, 0.38%; 95% CI, 0.28%-0.49%; *P* < .001 for trend). The increases in the estimated intake of total fat were associated with increases in estimated energy intake from saturated fatty acids (from 11.5% to 11.9%; difference, 0.36%; 95% CI, 0.20%-0.51%; *P* < .001 for trend), monounsaturated fatty acids (from 12.9% to 13.1%; difference, 0.19%; 95% CI, 0.03%-0.36%; *P* < .001 for trend), and polyunsaturated fatty acids (from 7.58% to 8.23%; difference, 0.65%; 95% CI, 0.56%-0.74%; *P* < .001 for trend). Similar

Table 1. Sociodemographic Characteristics of US Adults by NHANES Survey Cycle, 1999 to 2016

Characteristics	No. of Participants (Weighted %) ^a	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)
Age group, y									
20-34	1136 (30.0)	1320 (27.6)	1207 (29.5)	1378 (27.8)	1260 (27.7)	1442 (27.9)	1317 (27.7)	1321 (27.8)	1273 (27.8)
35-49	1035 (31.1)	1258 (33.1)	1044 (28.8)	1141 (30.1)	1369 (30.1)	1522 (28.9)	1178 (26.6)	1322 (26.1)	1244 (24.8)
50-64	929 (20.8)	1011 (22.4)	901 (24.0)	953 (24.1)	1395 (25.6)	1419 (25.8)	1274 (28.1)	1298 (27.4)	1290 (26.3)
≥65	1137 (18.0)	1155 (16.9)	1296 (17.7)	1048 (18.0)	1396 (16.6)	1379 (17.4)	1032 (17.6)	1106 (18.6)	1210 (21.1)
Sex									
Male	1978 (47.8)	2250 (48.2)	2135 (48.1)	2163 (48.0)	2662 (47.1)	2789 (48.2)	2394 (48.7)	2414 (48.5)	2415 (48.1)
Female	2259 (52.2)	2494 (51.8)	2313 (51.9)	2357 (52.0)	2758 (52.9)	2973 (51.8)	2407 (51.3)	2633 (51.5)	2602 (51.9)
Race/ethnicity									
Non-Hispanic white	1891 (69.8)	2494 (72.9)	2391 (73.0)	2276 (72.7)	2548 (70.2)	2786 (68.7)	1842 (66.6)	2233 (65.7)	1711 (64.4)
Non-Hispanic black	792 (10.8)	890 (10.6)	867 (11.2)	1012 (11.5)	1136 (11.3)	1025 (11.4)	1274 (11.5)	1009 (11.4)	1060 (11.0)
Hispanic	1421 (14.8)	1200 (12.3)	1016 (10.8)	1049 (10.6)	1525 (13.2)	1647 (13.6)	932 (14.3)	1125 (14.7)	1543 (15.0)
Other ^b	133 (4.6)	160 (4.1)	174 (5.0)	183 (5.2)	211 (5.3)	304 (6.3)	753 (7.7)	680 (8.2)	703 (9.6)
Education level ^c									
Less than high school graduate	1633 (24.6)	1421 (19.2)	1288 (18.1)	1234 (17.1)	1665 (20.1)	1634 (18.8)	1102 (16.3)	1028 (14.7)	1150 (13.8)
High school graduate or GED	957 (26.3)	1110 (24.7)	1111 (26.4)	1093 (25.4)	1341 (25.8)	1316 (22.5)	1008 (19.9)	1141 (22.3)	1108 (21.0)
Some college or above	1633 (49.1)	2207 (56.0)	2043 (55.4)	2191 (57.5)	2410 (54.1)	2799 (58.7)	2688 (63.8)	2875 (63.0)	2757 (65.3)
Ratio of family income to poverty level ^{c,d}									
<1.30	1106 (23.6)	1190 (21.1)	1209 (21.4)	1115 (17.4)	1498 (21.4)	1746 (22.2)	1564 (25.1)	1592 (25.1)	1429 (21.0)
1.30-3.49	1397 (35.7)	1723 (35.1)	1676 (37.5)	1703 (37.5)	1921 (34.1)	1973 (35.8)	1530 (33.8)	1615 (34.3)	1826 (36.7)
≥3.50	1137 (40.7)	1516 (43.8)	1326 (41.1)	1507 (45.2)	1516 (44.6)	1509 (42.0)	1340 (41.0)	1479 (40.6)	1282 (42.3)

Abbreviations: GED, general equivalency diploma; NHANES, National Health and Nutrition Examination Survey.

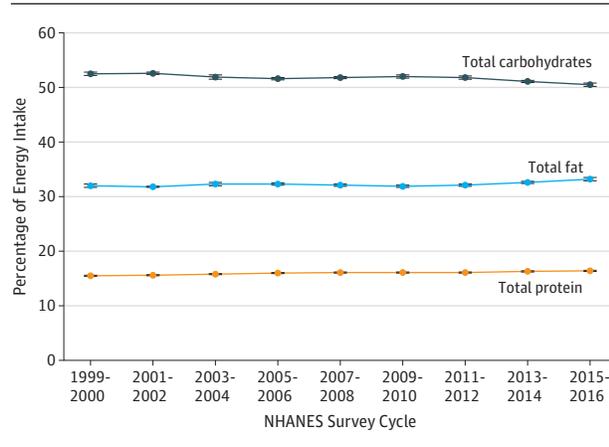
^a Percentages were adjusted for NHANES survey weights.

^b "Other" includes race/ethnicity other than non-Hispanic white, non-Hispanic black, and Hispanic, including multiracial.

^c Numbers may not sum to the total number of participants because of missing data (n=53 without education data; n=3571 without income data).

^d Represents the ratio of family income to the federal poverty threshold, adjusting for household size. A higher ratio indicates a higher level of income.

Figure 1. Trends in Estimated Percentage of Energy Intake From Total Carbohydrates, Protein, and Fat Among US Adults Aged 20 Years or Older by NHANES Survey Cycle From 1999-2000 to 2015-2016



NHANES indicates National Health and Nutrition Examination Survey. Data were adjusted for NHANES survey weights to be nationally representative. Error bars indicate 95% CIs. $P < .001$ for trend for all (decrease for total carbohydrates; increase for total protein and total fat).

trends were observed when the macronutrients were evaluated by energy-adjusted absolute intake in grams per day (eTable 3 in the Supplement) and when trends were examined from 2003 to 2016 (eTable 4 in the Supplement). After excluding 3624 participants with missing data on education and income, adjusting for changes in the sociodemographic characteristics over time did not alter the results (eTable 5 in the Supplement).

Carbohydrate and Protein Intake by Food Sources

From 1999 to 2016, increases in the estimated percentage of energy intake from high-quality carbohydrates were associated with increases in estimated carbohydrate intake from whole grains (from 2.00% to 2.65%; difference, 0.65%; 95% CI, 0.50%-0.79%; $P < .001$ for trend) and whole fruit (from 2.87% to 3.21%; difference, 0.34%; 95% CI, 0.13%-0.55%; $P = .002$ for trend) (Table 2). The declines in the estimated energy intake from low-quality carbohydrates were associated with decreases in estimated carbohydrate intake from added sugar (from 16.4% to 14.4%; difference, -2.00%; 95% CI, -2.68% to -1.33%; $P < .001$ for trend) and fruit juice (from 3.93% to 2.81%; difference, -1.12%; 95% CI, -1.39% to -0.84%; $P < .001$ for trend). The increases in the estimated energy intake from animal protein were associated with increases in estimated protein intake derived from poultry (from 2.38% to 2.54%; difference, 0.15%; 95% CI, 0.07%-0.24%; $P < .001$ for trend) and eggs (from 0.70% to 0.80%; difference, 0.10%; 95% CI, 0.08%-0.13%; $P < .001$ for trend). The increases in estimated energy intake from plant protein were associated with increases in estimated protein intake from whole grains (from 0.38% to 0.50%; difference, 0.12%; 95% CI, 0.09%-0.15%; $P < .001$ for trend), nuts (from 0.36% to 0.45%; difference, 0.09%; 95% CI, 0.05%-0.13%; $P < .001$ for trend), and soy (from 0.12% to 0.19%; difference, 0.07%; 95% CI, 0.04%-0.10%; $P < .001$ for trend). Similar trends were found in evaluation of

food sources by energy-adjusted absolute intake in grams per day (eTable 6 in the Supplement).

Healthy Eating Index 2015

From 1999 to 2016, the estimated mean of the HEI-2015 increased from 55.7 to 57.7 (difference, 2.01; 95% CI, 0.86-3.16; $P < .001$ for trend) (Table 3). The largest increase in the estimated component scores was observed for added sugar (from 5.68 to 6.84; difference, 1.17; 95% CI, 0.88-1.45; $P < .001$ for trend), indicating reduced consumption of sugar. The largest decrease was observed for sodium (from 4.39 to 3.83; difference, -0.56; 95% CI, -0.72 to -0.39; $P < .001$ for trend), corresponding to increased sodium consumption. No statistically significant trends were observed for component scores for fruit, dairy, and refined grains.

Trends in Population Subgroups

Participants with missing data on education ($n = 53$) and income ($n = 3571$) were excluded in the corresponding subgroup analyses. Between 1999 and 2016, there were significant declines in estimated percentage of energy intake from low-quality carbohydrates and increases in estimated percentage of energy intake from high-quality carbohydrates, plant and animal protein, and polyunsaturated fatty acids across all population subgroups ($P < .05$ for trend for all) (eTables 7-9 in the Supplement). Greater changes in low-quality carbohydrates and polyunsaturated fatty acids were observed among younger vs older individuals and among those with a higher vs lower level of education or income ($P < .001$ for interaction for all). For example, changes in estimated percentage of energy from low-quality carbohydrates and polyunsaturated fatty acids were greater among individuals with the highest level of income (-3.89% [95% CI, -4.67% to -3.11%] and 0.76% [95% CI, 0.57%-0.95%], respectively) than among those with the lowest level of income (-2.46% [95% CI, -3.11% to -1.82%] and 0.49% [95% CI, 0.35%-0.63%], respectively) ($P < .001$ for interaction for all). For the HEI-2015, greater increases in estimated total score were observed among younger vs older individuals and among those with a higher vs lower level of income ($P < .001$ for interaction for all) (eTable 10 in the Supplement).

Discussion

From 1999 to 2016, the macronutrient composition of the diet of US adults improved, with declines in low-quality carbohydrates (primarily added sugar) and increases in high-quality carbohydrates (primarily whole grains), plant protein (primarily whole grains and nuts), and polyunsaturated fatty acids, accompanied by improvements in overall diet quality as assessed by the HEI-2015. However, proportions of energy intake from low-quality carbohydrates remained high, while saturated fat intake remained above the recommended level.

The decreasing trend in total carbohydrate intake (from 52% to 50% of energy) and increasing trend in total fat intake (from 32% to 33%) in the past 18 years partly reversed the trends observed between 1971 and 2000, when the energy intake from

carbohydrates increased from 42%-45% to 49%-52% while intake from total fat decreased from 36%-37% to 32%.^{12,13} These opposing trends could be due to dietary guidelines prior to 2000 that recommended low-fat diets,²⁵ which was associated with decreased intake of total fat and increased intake of refined grains and added sugar. After 2000, shifts in scientific evidence and dietary guidelines promoted health benefits of healthy fats and plant sources of protein and the harms of low-quality carbohydrates.^{26,27} At the same time, the growing popularity of specific diet patterns such as Atkins, paleo, low-carbohydrate, and vegan/vegetarian diets may have contributed to changes in recent trends.

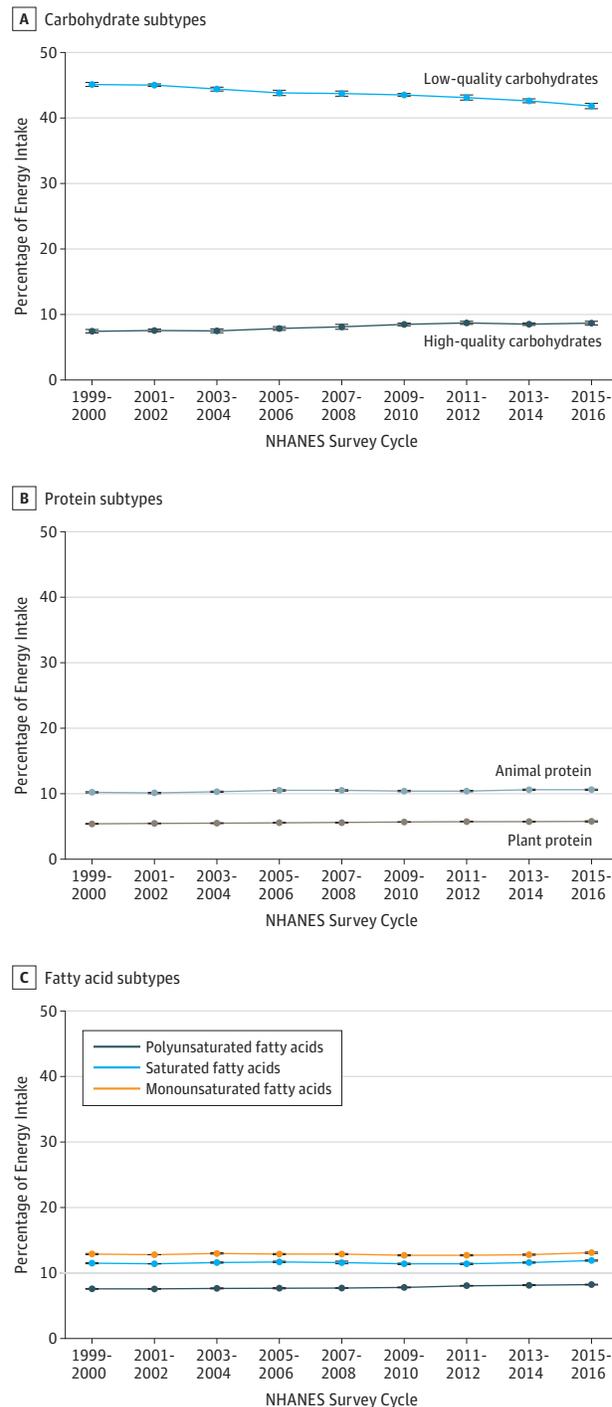
Several improvements in macronutrient composition and diet quality were identified. From 1999 to 2016, consistent with concurrent dietary guidance, US adults decreased intake of added sugar and increased consumption of whole grains, poultry, and nuts.^{26,27} The overall diet quality as measured by the HEI-2015 improved as well, consistent with previous studies evaluating other diet quality scores such as the Alternative Healthy Eating Index 2010 and the American Heart Association Diet Score.^{28,29} However, the improvement in the HEI-2015 was small in magnitude and of uncertain clinical importance. Despite observed improvements, important dietary challenges remained. First, US adults still consumed a disproportionately high energy intake from low-quality carbohydrates. The majority of the low-quality carbohydrate energy intake represented carbohydrates from refined grains, fruit juice, and potatoes (21.2% of intake), followed by added sugars in foods and beverages (14.4% of intake). Second, protein intake was mostly derived from animal foods such as unprocessed red meat and processed meat, whereas protein intake from seafood and plant sources such as whole grains, nuts, and legumes remained a much smaller percentage of energy intake. Previous studies showed that red meat and processed meat were associated with poorer health outcomes.^{9,30,31} Third, saturated fat intake remained above the Dietary Guidelines for Americans recommended level of 10% of energy intake.²⁶ Fourth, US adults with low income and educational attainment experienced a smaller improvement in macronutrient composition and did not improve the overall diet quality in the past 18 years. Further interventions should focus on minimizing these differences.

This study's strengths included use of the most recent dietary data from NHANES, thereby facilitating evaluation of trends in the past 18 years, investigation of the trends of macronutrients by quality and food sources, and examination of potential differences by sociodemographic subgroups.

Limitations

This study has several limitations. First, self-reported dietary 24-hour recall data are subject to measurement error due to large day-to-day variations in food intake. However, the NCI method was applied to reduce measurement error and improve estimates of usual intake. Second, changes in dietary databases and dietary assessment methods over the study period may affect estimated trends in macronutrient intake. Still, the same protocols were followed to derive each macronutrient from different foods across all cycles. The sen-

Figure 2. Trends in Estimated Percentage of Energy Intake From Subtypes of Carbohydrates, Protein, and Fat Among US Adults Aged 20 Years or Older by NHANES Survey Cycle From 1999-2000 to 2015-2016



NHANES indicates National Health and Nutrition Examination Survey. Data were adjusted for NHANES survey weights to be nationally representative. Error bars indicate 95% CIs. $P < .001$ for trend for all (decrease for low-quality carbohydrates; increase for all others).

sitivity analyses restricted to cycles using the same dietary database and assessment method showed results similar to

Table 2. Trends in Estimated Percentage of Energy Intake From Carbohydrates and Protein From Different Sources Among Adults Aged 20 Years or Older by NHANES Survey Cycle, 1999 to 2016

	Estimated Energy Intake, Survey-Weighted Mean % (95% CI) ^a										Difference, 2015-2016 vs 1999-2000 (95% CI) ^b	P Value for Trend
	1999-2000 (n = 4237)	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)			
Carbohydrates												
High-quality sources												
Whole grains	2.00 (1.93-2.08)	2.15 (2.08-2.23)	2.09 (1.99-2.18)	2.28 (2.17-2.39)	2.32 (2.18-2.45)	2.47 (2.39-2.55)	2.60 (2.48-2.72)	2.56 (2.48-2.64)	2.65 (2.53-2.77)	0.65 (0.50 to 0.79)	<.001	
Whole fruits	2.87 (2.72-3.03)	2.89 (2.80-2.98)	2.86 (2.69-3.03)	3.03 (2.89-3.17)	3.19 (3.01-3.37)	3.34 (3.25-3.43)	3.30 (3.17-3.43)	3.19 (3.07-3.32)	3.21 (3.06-3.36)	0.34 (0.13 to 0.55)	<.001	
Nonstarchy vegetables	1.67 (1.63-1.70)	1.67 (1.64-1.69)	1.70 (1.66-1.74)	1.71 (1.67-1.76)	1.71 (1.67-1.75)	1.75 (1.72-1.79)	1.84 (1.80-1.88)	1.81 (1.78-1.84)	1.81 (1.77-1.85)	0.14 (0.08 to 0.20)	<.001	
Legumes	0.88 (0.82-0.94)	0.84 (0.79-0.89)	0.83 (0.77-0.89)	0.82 (0.77-0.88)	0.87 (0.81-0.93)	0.90 (0.83-0.97)	0.96 (0.90-1.02)	0.94 (0.90-0.99)	0.98 (0.93-1.03)	0.10 (0.02 to 0.18)	<.001	
Low-quality sources												
Refined grains	15.2 (15.0-15.5)	15.3 (15.1-15.5)	15.1 (14.9-15.3)	15.1 (14.9-15.3)	15.3 (15.1-15.5)	15.5 (15.3-15.8)	15.9 (15.7-16.1)	15.9 (15.7-16.0)	15.9 (15.6-16.2)	0.69 (0.31 to 1.07)	<.001	
Fruit juice	3.93 (3.70-4.15)	3.93 (3.76-4.10)	3.84 (3.55-4.13)	3.64 (3.43-3.85)	3.45 (3.25-3.65)	3.48 (3.35-3.61)	3.33 (3.02-3.63)	2.87 (2.74-2.99)	2.81 (2.65-2.98)	-1.12 (-1.39 to -0.84)	<.001	
Potato	2.49 (2.42-2.55)	2.49 (2.45-2.53)	2.51 (2.44-2.58)	2.51 (2.43-2.58)	2.53 (2.46-2.60)	2.49 (2.44-2.54)	2.45 (2.40-2.49)	2.47 (2.43-2.51)	2.50 (2.46-2.55)	0.02 (-0.06 to 0.10)	.47	
Other starchy vegetable	0.58 (0.57-0.60)	0.59 (0.58-0.60)	0.59 (0.58-0.61)	0.61 (0.59-0.64)	0.61 (0.60-0.63)	0.60 (0.59-0.61)	0.59 (0.58-0.61)	0.59 (0.58-0.60)	0.59 (0.58-0.61)	0.01 (-0.01 to 0.03)	.10	
Added sugar	16.4 (15.8-16.9)	16.1 (15.8-16.5)	15.6 (15.2-16.1)	15.0 (14.6-15.4)	15.1 (14.6-15.6)	14.9 (14.6-15.1)	14.8 (14.4-15.1)	14.7 (14.4-15.0)	14.4 (13.9-14.8)	-2.00 (-2.68 to -1.33)	<.001	
Other sources ^c	6.46 (6.39-6.53)	6.61 (6.53-6.70)	6.78 (6.63-6.93)	6.96 (6.86-7.06)	6.69 (6.56-6.81)	6.51 (6.44-6.59)	6.03 (5.91-6.15)	6.06 (5.94-6.17)	5.61 (5.49-5.73)	-0.85 (-0.99 to -0.71)	<.001	
Protein												
Animal sources												
Unprocessed red meat	2.70 (2.67-2.73)	2.66 (2.62-2.70)	2.73 (2.68-2.77)	2.74 (2.69-2.78)	2.74 (2.69-2.78)	2.72 (2.67-2.76)	2.73 (2.67-2.79)	2.73 (2.70-2.76)	2.75 (2.70-2.79)	0.05 (-0.01 to 0.10)	.09	
Processed meat	1.10 (1.07-1.12)	1.11 (1.09-1.13)	1.13 (1.09-1.17)	1.14 (1.10-1.18)	1.12 (1.10-1.15)	1.11 (1.08-1.15)	1.11 (1.08-1.13)	1.11 (1.08-1.14)	1.11 (1.09-1.13)	0.01 (-0.02 to 0.05)	.76	
Poultry	2.38 (2.34-2.43)	2.36 (2.32-2.41)	2.39 (2.33-2.45)	2.44 (2.39-2.50)	2.50 (2.43-2.57)	2.47 (2.40-2.54)	2.46 (2.39-2.54)	2.54 (2.49-2.59)	2.54 (2.46-2.61)	0.15 (0.07 to 0.24)	<.001	
Seafood	0.75 (0.73-0.77)	0.73 (0.72-0.75)	0.76 (0.73-0.79)	0.78 (0.75-0.81)	0.78 (0.75-0.81)	0.79 (0.77-0.82)	0.80 (0.77-0.83)	0.81 (0.77-0.85)	0.81 (0.77-0.84)	0.06 (0.02 to 0.10)	<.001	
Dairy	2.54 (2.50-2.57)	2.55 (2.51-2.59)	2.55 (2.48-2.63)	2.61 (2.55-2.66)	2.57 (2.49-2.66)	2.60 (2.56-2.63)	2.50 (2.43-2.57)	2.58 (2.53-2.64)	2.60 (2.51-2.69)	0.06 (-0.03 to 0.16)	.10	
Eggs	0.70 (0.69-0.71)	0.69 (0.68-0.71)	0.70 (0.67-0.72)	0.74 (0.72-0.76)	0.75 (0.73-0.77)	0.75 (0.72-0.77)	0.75 (0.74-0.77)	0.78 (0.77-0.80)	0.80 (0.78-0.82)	0.10 (0.08 to 0.13)	<.001	
Other animal sources ^d	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.01 (0.00-0.01)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.01 (0.01-0.01)	0.00 (0.00 to 0.00)	<.001	
Plant sources												
Whole grains	0.38 (0.37-0.40)	0.41 (0.40-0.43)	0.40 (0.38-0.42)	0.44 (0.42-0.46)	0.45 (0.42-0.48)	0.47 (0.46-0.49)	0.52 (0.49-0.55)	0.51 (0.49-0.53)	0.50 (0.48-0.53)	0.12 (0.09 to 0.15)	<.001	
Refined grains	2.65 (2.62-2.68)	2.68 (2.66-2.71)	2.68 (2.66-2.71)	2.67 (2.64-2.69)	2.68 (2.66-2.71)	2.69 (2.67-2.72)	2.70 (2.67-2.72)	2.69 (2.67-2.71)	2.67 (2.63-2.70)	0.02 (-0.03 to 0.06)	.33	
Nuts	0.36 (0.34-0.38)	0.37 (0.36-0.38)	0.39 (0.37-0.41)	0.40 (0.39-0.42)	0.39 (0.37-0.41)	0.41 (0.39-0.43)	0.43 (0.41-0.45)	0.44 (0.42-0.47)	0.45 (0.42-0.49)	0.09 (0.05 to 0.13)	<.001	
Legumes	0.31 (0.29-0.33)	0.29 (0.28-0.31)	0.29 (0.27-0.31)	0.29 (0.27-0.31)	0.31 (0.29-0.32)	0.31 (0.29-0.32)	0.33 (0.31-0.35)	0.33 (0.31-0.34)	0.34 (0.32-0.36)	0.04 (0.01 to 0.06)	<.001	
Soy	0.12 (0.10-0.13)	0.12 (0.11-0.13)	0.15 (0.13-0.16)	0.15 (0.13-0.17)	0.15 (0.14-0.17)	0.16 (0.15-0.17)	0.15 (0.13-0.16)	0.15 (0.14-0.17)	0.19 (0.17-0.22)	0.07 (0.04 to 0.10)	<.001	
Other plant sources ^e	1.55 (1.54-1.57)	1.57 (1.56-1.59)	1.59 (1.57-1.60)	1.62 (1.59-1.65)	1.60 (1.59-1.62)	1.63 (1.61-1.65)	1.62 (1.59-1.65)	1.61 (1.58-1.64)	1.60 (1.57-1.64)	0.05 (0.01 to 0.09)	<.001	

Abbreviation: NHANES, National Health and Nutrition Examination Survey.

^a Data were adjusted for NHANES survey weights to be nationally representative.

^b Values may not equal the difference between the beginning and ending estimates because of rounding.

^c Residual carbohydrates not from individual food groups (eg, dairy foods).
^d Residual animal protein not from individual food groups (eg, insects).
^e Residual plant protein not from individual food groups (eg, fruits and vegetables).

Table 3. Trends in Estimated Healthy Eating Index (HEI) 2015 Total and Component Scores Among Adults Aged 20 Years or Older by NHANES Survey Cycle, 1999 to 2016

HEI-2015 Scores	Survey-Weighted Mean (95% CI) ^a										Difference, 2015-2016 vs 1999-2000 (95% CI) ^b	P Value for Trend
	1999-2000 (n = 4237)	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)			
Total score (0-100)	55.7 (54.8-56.6)	56.2 (55.6-56.7)	55.4 (54.6-56.1)	56.6 (56.0-57.2)	56.9 (56.0-57.8)	57.6 (57.2-58.0)	58.2 (57.6-58.7)	57.8 (57.3-58.2)	57.7 (57.0-58.5)	2.01 (0.86 to 3.16)	<.001	
Component scores												
Adequacy components												
Total vegetables (0-5)	3.52 (3.48-3.55)	3.50 (3.46-3.54)	3.54 (3.51-3.58)	3.59 (3.53-3.65)	3.60 (3.56-3.64)	3.58 (3.55-3.61)	3.60 (3.56-3.64)	3.55 (3.50-3.59)	3.60 (3.55-3.64)	0.08 (0.02 to 0.14)	<.001	
Greens and beans (0-5)	2.60 (2.51-2.70)	2.55 (2.47-2.62)	2.48 (2.40-2.56)	2.69 (2.58-2.80)	2.73 (2.62-2.84)	2.75 (2.67-2.82)	2.85 (2.77-2.93)	2.88 (2.79-2.96)	2.95 (2.87-3.03)	0.35 (0.22 to 0.47)	<.001	
Total fruits (0-5)	2.80 (2.67-2.93)	2.86 (2.78-2.95)	2.75 (2.60-2.90)	2.80 (2.71-2.89)	2.82 (2.69-2.94)	2.91 (2.86-2.96)	2.86 (2.79-2.93)	2.77 (2.68-2.85)	2.77 (2.66-2.87)	-0.03 (-0.20 to 0.14)	.07	
Whole fruits (0-5)	3.11 (2.99-3.23)	3.16 (3.09-3.23)	3.00 (2.86-3.14)	3.11 (3.01-3.20)	3.20 (3.08-3.32)	3.26 (3.21-3.31)	3.26 (3.17-3.36)	3.24 (3.15-3.32)	3.25 (3.13-3.37)	0.14 (-0.03 to 0.31)	.006	
Whole grains (0-10)	2.24 (2.17-2.32)	2.42 (2.34-2.51)	2.32 (2.22-2.41)	2.53 (2.43-2.62)	2.55 (2.44-2.65)	2.74 (2.67-2.81)	2.86 (2.74-2.98)	2.81 (2.74-2.88)	2.81 (2.68-2.94)	0.56 (0.41 to 0.72)	<.001	
Total dairy (0-10)	5.64 (5.54-5.74)	5.58 (5.50-5.66)	5.57 (5.42-5.73)	5.78 (5.68-5.88)	5.72 (5.55-5.88)	5.89 (5.81-5.97)	5.67 (5.53-5.81)	5.71 (5.61-5.82)	5.59 (5.42-5.76)	-0.06 (-0.25 to 0.14)	<.001	
Total protein foods (0-5)	4.11 (4.04-4.17)	4.90 (4.89-4.92)	4.87 (4.85-4.90)	4.90 (4.88-4.91)	4.90 (4.89-4.92)	4.90 (4.88-4.91)	4.91 (4.89-4.93)	4.91 (4.90-4.92)	4.93 (4.92-4.94)	0.02 (0.01 to 0.04)	<.001	
Seafood and plant protein (0-5)	4.56 (4.47-4.65)	4.62 (4.53-4.70)	4.63 (4.57-4.70)	4.47 (4.39-4.56)	4.63 (4.48-4.77)	4.72 (4.61-4.82)	4.95 (4.83-5.06)	4.81 (4.71-4.90)	4.74 (4.63-4.86)	0.18 (0.04 to 0.33)	<.001	
Moderation components												
Sodium (0-10)	4.39 (4.29-4.49)	4.55 (4.47-4.63)	4.35 (4.23-4.47)	4.18 (4.04-4.32)	4.16 (4.07-4.25)	3.80 (3.70-3.90)	3.92 (3.85-3.98)	3.89 (3.78-4.00)	3.83 (3.70-3.96)	-0.56 (-0.72 to -0.39)	<.001	
Refined grains (0-10)	6.18 (6.06-6.29)	6.14 (6.04-6.25)	6.04 (5.93-6.14)	6.24 (6.12-6.35)	6.18 (6.05-6.32)	6.25 (6.10-6.40)	6.27 (6.12-6.43)	6.30 (6.17-6.43)	6.38 (6.18-6.57)	0.20 (-0.03 to 0.42)	.03	
Saturated fat (0-10)	5.97 (5.82-6.12)	6.10 (6.01-6.19)	5.85 (5.68-6.02)	5.77 (5.68-5.86)	5.91 (5.76-6.05)	6.13 (6.00-6.26)	6.20 (6.05-6.35)	5.98 (5.85-6.10)	5.69 (5.57-5.82)	-0.27 (-0.47 to -0.08)	<.001	
Added sugars (0-10)	5.68 (5.44-5.91)	5.80 (5.61-5.98)	6.14 (5.92-6.36)	6.39 (6.22-6.57)	6.31 (6.09-6.53)	6.48 (6.37-6.59)	6.55 (6.40-6.71)	6.65 (6.53-6.77)	6.84 (6.69-7.00)	1.17 (0.88 to 1.45)	<.001	

Abbreviations: MUFAs, monounsaturated fatty acids; NHANES, National Health and Nutrition Examination Survey; PUFAs, polyunsaturated fatty acids; SFAs, saturated fatty acids.

^a Data were adjusted for NHANES survey weights to be nationally representative. Higher scores indicate greater adherence to the 2015 Dietary Guidelines for Americans.

^b Values may not equal the difference between the beginning and ending estimates because of rounding.

the main analyses. Third, a multiple-step process was developed to estimate food sources of protein and carbohydrate, but this method requires further replication and validation. Fourth, the cross-sectional nature of the NHANES survey precluded conclusions on how demographic shifts contributed to these trends. Fifth, participants with missing data on education or income were excluded, which may affect the generalizability of these findings. Sixth, no data were available on associations of these dietary changes with population outcomes.

Conclusions

From 1999 to 2016, US adults experienced a significant decrease in percentage of energy intake from low-quality carbohydrates and significant increases in percentage of energy intake from high-quality carbohydrates, plant protein, and polyunsaturated fat. Despite improvements in macronutrient composition and diet quality, continued high intake of low-quality carbohydrates and saturated fat remained.

ARTICLE INFORMATION

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