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Trends in Diet Quality Among Youth in the United States, 1999-2016

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IMPORTANCE Prior studies of dietary trends among US youth have evaluated major macronutrients or only a few foods or have used older data.

OBJECTIVE To characterize trends in diet quality among US youth.

DESIGN, SETTING, AND PARTICIPANTS Serial cross-sectional investigation using 24-hour dietary recalls from youth aged 2 to 19 years from 9 National Health and Nutrition Examination Survey (NHANES) cycles (1999-2016).

EXPOSURES Calendar year and population sociodemographic characteristics.

MAIN OUTCOMES AND MEASURES The primary outcomes were the survey-weighted, energy-adjusted mean consumption of dietary components and proportion meeting targets of the American Heart Association (AHA) 2020 continuous diet score (range, 0-50; based on total fruits and vegetables, whole grains, fish and shellfish, sugar-sweetened beverages, and sodium). Additional outcomes were the AHA secondary score (range, 0-80; adding nuts, seeds, and legumes; processed meat; and saturated fat) and Healthy Eating Index (HEI) 2015 score (range, 0-100). Poor diet was defined as less than 40% adherence (scores, <20 for primary and <32 for secondary AHA scores); intermediate as 40% to 79.9% adherence (scores, 20-39.9 and 32-63.9, respectively); and ideal, as at least 80% adherence (scores, ≥40 and ≥64, respectively). Higher diet scores indicate better diet quality; a minimal clinically important difference has not been quantified.

RESULTS Of 31 420 youth aged 2 to 19 years included, the mean age was 10.6 years; 49.1% were female. From 1999 to 2016, the estimated AHA primary diet score significantly increased from 14.8 (95% CI, 14.1-15.4) to 18.8 (95% CI, 18.1-19.6) (27.0% improvement), the estimated AHA secondary diet score from 29.2 (95% CI, 28.1-30.4) to 33.0 (95% CI, 32.0-33.9) (13.0% improvement), and the estimated HEI-2015 score from 44.6 (95% CI, 43.5-45.8) to 49.6 (95% CI, 48.5-50.8) (11.2% improvement) ($P < .001$ for trend for each). Based on the AHA primary diet score, the estimated proportion of youth with poor diets significantly declined from 76.8% (95% CI, 72.9%-80.2%) to 56.1% (95% CI, 51.4%-60.7%) and with intermediate diets significantly increased from 23.2% (95% CI, 19.8%-26.9%) to 43.7% (95% CI, 39.1%-48.3%) ($P < .001$ for trend for each). The estimated proportion meeting ideal quality significantly increased but remained low, from 0.07% (95% CI, 0.01%-0.49%) to 0.25% (95% CI, 0.10%-0.62%) ($P = .03$ for trend). Persistent dietary variations were identified across multiple sociodemographic groups. The estimated proportion of youth with a poor diet in 2015-2016 was 39.8% (95% CI, 35.1%-44.5%) for ages 2 to 5 years (unweighted n = 666), 52.5% (95% CI, 46.4%-58.5%) for ages 6 to 11 years (unweighted n = 1040), and 66.6% (95% CI, 61.4%-71.4%) for ages 12 to 19 years (unweighted n = 1195), with persistent differences across levels of parental education, household income, and household food security status.

CONCLUSIONS AND RELEVANCE Based on serial NHANES surveys from 1999 to 2016, the estimated overall diet quality of US youth showed modest improvement, but more than half of youth still had poor-quality diets.

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Supplemental content

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Poor diet is a major contributor to chronic diseases, including diabetes, heart disease, stroke, cancers, and obesity, accounting for substantial morbidity and premature mortality.[1] Diets at early ages shape lifelong food preferences and health outcomes.[2] Several national efforts since 2000 have aimed to improve the food available to and consumed by US children.[3-5] At the same time, industry and market forces have increased the proportion of meals prepared outside of home, more than one-third of US calories consumed in 2011-2012[6]; have aggressively marketed foods of low nutritional value to children[7,8]; and may have led to more products with whole grains and less added sugar.[9,10]

Prior studies have generally focused on a few components (eg, total energy, macronutrients) or a few foods (eg, sugary beverages, processed meat), or used older data and diet quality measures.[11-15] Contemporary trends in diet quality of US youth across a broad range of dietary factors, including both dietary patterns and multiple individual foods and nutrients linked to major health outcomes, are not established. In addition, differences in trends across population subgroups in overall diet quality and major food groups and nutrients remain unclear. Understanding these trends is crucial to inform priorities and policies to help improve diets and long-term health among US youth.

To address these major knowledge gaps, data from the National Health and Nutrition Examination Survey (NHANES) from 1999-2000 to 2015-2016 were evaluated to examine trends in diet quality and individual foods and nutrients consumed by US youth, overall and by age, sex, race/ethnicity, parental education, household income, household food security status, and federal food assistance program participation.

Key Points

Question What was the quality of diets among youth in the United States and how did it change between 1999 and 2016?

Findings In this serial cross-sectional analysis of nationally representative data from 31 420 youth, diet quality modestly improved from 1999-2000 to 2015-2016 based on validated dietary quality scores. The estimated proportion of children with poor-quality diet significantly decreased (from 76.8% to 56.1%), the estimated proportion with intermediate quality diet significantly increased (from 23.2% to 43.7%), and the estimated proportion with an ideal quality significantly increased but remained low (from 0.07% to 0.25%).

Meaning From 1999 to 2016, the estimated overall diet quality of US youth modestly improved, but more than half of children still had poor-quality diets.

Methods

Data Source, Study Population, and Dietary Assessment

NHANES is a series of cross-sectional surveys using a complex, multistage probability design to sample the civilian, noninstitutionalized population residing in the 50 states and District of Columbia. The NHANES protocol was approved by the Centers for Disease Control and Prevention/National Center for Health Statistics Ethics Review Board, and all participants provided written informed consent. Because the data are publicly available and deidentified, institutional review board approval was not required for this analysis. Details on the study design, protocol, and data collection methods have been documented.[16] The overall response rate was 83.5%, with the cycle-specific rate ranging from 67.3% to 89.0%.

This investigation used data across 9 cycles of NHANES (1999-2000 through 2015-2016) including US youth aged 2 to 19 years who completed at least 1 valid 24-hour diet recall. All participants were eligible for dietary assessment, consisting of 1 (first 2 cycles) or up to 2 (later cycles) dietary recalls in which respondents reported all foods and beverages consumed during the previous 24 hours (midnight to midnight). Survey participants aged 12 years or older completed the dietary interview on their own. Proxy-assisted interviews were conducted for children aged 6 to 11 years, and proxy respondents reported diets for children who were aged 5 years or younger or for persons who could not self-report. The US Department of Agriculture (USDA) Automated Multiple-Pass Method was used for collecting 24-hour dietary recalls using "What We Eat In America," the dietary interview component of NHANES.

The USDA Food Patterns Equivalents Database and MyPyramid Equivalents Database, which disaggregate mixed foods into their component parts, were used to assess changes in specific food groups. Nutrients were derived from cycle-specific versions of the USDA Food and Nutrient Database for Dietary Studies. Intakes of all dietary components were energy adjusted using the residual method to evaluate trends in dietary quality (composition) independent of the small changes in energy intake during this period, which could relate to nondietary factors such as changes in physical activity, and to minimize measurement error in dietary estimates.

Assessment of Dietary Quality

The primary outcomes were the mean consumption of dietary components and proportion meeting targets of the American Heart Association (AHA) 2020 continuous diet score (range, 0-50; based on total fruits and vegetables, whole grains, fish and shellfish, sugar-sweetened beverages, and sodium).[17,18] We also evaluated the AHA secondary score (range, 0-80; adding nuts, seeds, and legumes; processed meat; and saturated fat), the Healthy Eating Index (HEI) 2015 score (range, 0-100), the individual components, and other food groups and nutrients linked to major health outcomes and of current policy or general public interest, including fish and shellfish, total fat, seafood omega-3 fat, protein, carbohydrate, cholesterol, fiber, potassium, and calcium. For calculating the AHA diet scores, intake of each dietary component was scored from 0 to 10 (beneficial components) and from 10 to 0 (harmful components) (eAppendix 1 and eTables 1 and 2 in the Supplement). Poor diet was defined as less than 40% adherence (scores, <20 for primary and <32 for secondary AHA scores); intermediate as 40% to 79.9% adherence (scores, 20-39.9 and 32-63.9, respectively); and ideal as at least 80% adherence (scores, ≥40 and ≥64, respectively). Higher diet scores indicate better diet quality; a minimal

clinically important difference has not been quantified. The HEI-2015 score, a government measure of adherence to the *Dietary Guidelines for Americans*,[19] was based on 9 adequacy food components (total fruits including 100% fruit juice, whole fruits, total vegetables including legumes, greens and beans, whole grains, total dairy, total protein foods, seafood and plant proteins, and the ratio of unsaturated to saturated fatty acids) and 4 moderation components (refined grains, sodium, added sugars, and saturated fats) (eTable 2 in the Supplement).

Assessment of Sociodemographic Characteristics

Trends in diet quality and intakes of major food groups and nutrients were evaluated by age (2-5, 6-11, and 12-19 years), sex, race/ethnicity (non-Hispanic white, non-Hispanic black, and Mexican American), parental educational level (less than high school diploma, 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 household food security status. We evaluated information on race/ethnicity because of previously documented differences in diet quality and diet-related health outcomes depending on race/ethnicity.[1,17] Information on race/ethnicity was collected by trained NHANES interviewers according to the fixed categories provided by the National Center for Health Statistics using the Computer-Assisted Personal Interview system, with classification identified by a household proxy for participants younger than 16 years and by the respondents directly for those aged 16 years and older. Information on household food security was collected by trained NHANES interviewers using the US Food Security Survey Module, including 18 items for households with children. The data derived from these responses were used by the National Center for Health Statistics to characterize the food security status of the entire household, used for this analysis. In addition, we evaluated population subgroups according to household participation in major federal nutrition assistance programs, including the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), the Supplemental Nutrition Assistance Program (SNAP), and the reduced-price/free National School Lunch Program/School Breakfast Program (eAppendix 2 in the Supplement).

Statistical Analysis

All analyses accounted for the NHANES complex sampling design to derive nationally representative estimates. The estimated population means for total and component diet scores and intakes of major foods and nutrients were calculated for each NHANES cycle. The estimated proportions of youth adherent to the recommended AHA score targets (ie, poor, intermediate, or ideal quality) were also calculated. The statistical significance of trends was assessed by treating the survey year as a continuous variable in a survey-weighted linear regression model. Absolute and relative (percentage change) differences in estimated means with 95% CIs between 1999-2000 and 2015-2016 cycles were calculated using survey-weighted linear regression by treating each 2-year survey cycle as an indicator category, with the 1999-2000 cycle as the reference. To assess the statistical significance of population differences (interaction) in trends over time, a survey-weighted Wald *F* test was used to evaluate a multiplicative interaction term between the survey year as a continuous variable and each sociodemographic subgroup as an indicator category.

To calculate HEI-2015 scores, we used the simple scoring algorithm in the main analysis. The National Cancer Institute and USDA generally recommend the population ratio method, which adjusts for day-to-day within-person variation to derive a score that is closer to the usual population intake distribution in sensitivity analyses.[20] We also used the more advanced and time-intensive Markov chain Monte Carlo method, which incorporates adjustment for measurement error, episodic consumption, skewness, and correlations between each and all of the included dietary factors and energy (eAppendix 1 and eTable 3 in the Supplement).[19]

To understand the extent to which observed trends over time might be associated with shifts in population demographic factors, sensitivity analyses were adjusted for age, sex, and race/ethnicity within each cycle, and statistically significant trend coefficients were evaluated before and after adjustment to quantify the percentage change in the coefficient. Participants with missing data on parental education, household income, or food security status were excluded from corresponding subgroup analyses. All analyses were performed using Stata version 14 (StataCorp) and SAS version 9.4 (SAS Institute Inc), with a 2-sided $\alpha = .05$. No adjustments were made for multiple comparisons, and findings of secondary analyses should be interpreted as exploratory.

Results

Participant Characteristics

A total of 31 420 youth (mean age, 10.6 years; 49.1% female) who completed at least 1 valid 24-hour diet recall were included in this analysis, including 20 193 (64.3%) who also provided a second recall. From 1999 to 2016, the proportion of non-Hispanic white youth decreased from 59.6% to 50.6%, while the proportion of Mexican American youth increased from 11.0% to 16.3% (**Table 1**). The proportion of children with parents having a college degree or higher increased from 20.2% to 27.1%, while the proportion of youth participating in SNAP increased from 16.7% to 27.6% (corresponding to the period of the US economic recession after 2007).

Trends in Dietary Quality

From 1999 to 2016, estimated overall dietary quality improved, whether based on the AHA primary score, AHA secondary score, or HEI-2015 score (**Table 2**). The estimated mean primary AHA score significantly increased from 14.8 (95% CI, 14.1-15.4) to 18.8 (95% CI, 18.1-19.6) out of 50 (an improvement of 27.0%), the estimated mean secondary AHA score significantly increased from 29.2 (95% CI, 28.1-30.4) to 33.0 (95% CI, 32.0-33.9) out of 80 (an improvement of 13%), and the estimated mean HEI-2015 score significantly increased from 44.6 (95% CI, 43.5-45.8) to 49.6 (95% CI,

Table 1. Sociodemographic Characteristics of US Youth Aged 2 to 19 Years by NHANES Survey Cycles From 1999 to 2016

Characteristics	No. of participants (survey-weighted %)[a]								
	1999-2000 (n = 3833)	2001-2002 (n = 4288)	2003-2004 (n = 3825)	2005-2006 (n = 4029)	2007-2008 (n = 3109)	2009-2010 (n = 3280)	2011-2012 (n = 3134)	2013-2014 (n = 3021)	2015-2016 (n = 2901)
Age group, y									
2-5	665 (21.9)	856 (21.4)	763 (21.3)	902 (21.6)	832 (22.2)	861 (22.2)	836 (22.0)	678 (20.4)	666 (21.5)
6-11	961 (34.3)	1136 (33.8)	900 (33.0)	1012 (32.3)	1121 (32.3)	1154 (32.9)	1146 (32.8)	1047 (33.7)	1040 (33.5)
12-19	2207 (43.8)	2296 (44.8)	2162 (45.7)	2115 (46.0)	1156 (45.5)	1265 (44.9)	1152 (45.2)	1296 (45.9)	1195 (45.0)
Sex									
Female	1893 (48.8)	2158 (49.9)	1923 (48.4)	2046 (49.0)	1497 (49.7)	1568 (49.7)	1548 (48.8)	1501 (48.6)	1438 (49.4)
Male	1940 (51.2)	2130 (50.0)	1902 (51.6)	1983 (51.0)	1612 (50.3)	1712 (50.3)	1586 (51.2)	1520 (51.4)	1463 (50.6)
Race/ethnicity									
Non-Hispanic white	839 (59.6)	1325 (61.1)	1067 (62.9)	1075 (60.5)	991 (59.6)	1101 (57.3)	690 (53.2)	812 (52.7)	831 (50.6)
Non-Hispanic black	1052 (14.2)	1312 (14.4)	1322 (15.0)	1251 (14.9)	788 (14.8)	654 (13.8)	936 (15.2)	753 (14.0)	655 (14.6)
Mexican American	1588 (11.0)	1263 (12.1)	1139 (12.5)	1338 (13.3)	778 (13.2)	914 (14.3)	601 (14.8)	692 (16.0)	630 (16.3)
Other Hispanic	198 (7.5)	203 (6.4)	126 (3.8)	134 (3.7)	398 (6.9)	374 (7.1)	364 (8.0)	305 (7.4)	359 (8.6)
Other/mixed	156 (7.7)	185 (6.1)	171 (5.8)	231 (7.7)	154 (5.5)	237 (7.5)	543 (8.8)	459 (9.8)	426 (9.9)
Parental education									
Total No.	3637	4134	3673	3854	2997	3184	3023	2950	2786
Less than high school diploma	1555 (25.0)	1498 (23.2)	1224 (19.7)	1212 (17.7)	923 (19.5)	966 (20.0)	848 (23.4)	704 (16.5)	679 (18.3)
High school graduate or GED	880 (25.2)	982 (23.9)	958 (25.7)	917 (24.3)	753 (24.4)	738 (20.1)	674 (19.2)	701 (23.5)	581 (18.5)
Some college	758 (24.9)	947 (22.9)	1043 (33.3)	1096 (32.9)	834 (28.1)	885 (29.7)	824 (29.0)	901 (30.5)	907 (32.3)
College degree or higher	444 (20.2)	707 (26.5)	448 (17.2)	629 (21.3)	487 (23.0)	595 (27.2)	677 (25.4)	644 (26.8)	619 (27.1)
Ratio of family income to poverty level[b]									
Total No.	3297	4037	3655	3851	2878	3000	2909	2826	2669
<1.30	1566 (37.9)	1697 (32.8)	1678 (34.9)	1580 (28.0)	1296 (33.3)	1422 (33.9)	1383 (38.7)	1372 (37.4)	1074 (31.0)
1.30 to <1.85	473 (12.4)	543 (11.9)	498 (10.9)	484 (10.3)	358 (10.8)	406 (12.1)	402 (12.0)	336 (10.6)	408 (12.9)
1.85 to <3.00	537 (17.5)	699 (18.9)	633 (19.6)	695 (21.9)	524 (17.7)	441 (16.5)	415 (17.4)	414 (17.4)	529 (20.7)
≥3.00	721 (32.1)	1098 (36.4)	846 (34.6)	1092 (39.8)	700 (38.1)	731 (37.4)	709 (31.8)	704 (34.6)	658 (35.4)
Food security status[c]									
Total No.	3758	4046	3659	3979	3091	3250	3124	2999	NA
Very low food security	255 (4.6)	314 (6.2)	341 (6.8)	293 (5.2)	254 (6.3)	290 (6.9)	254 (7.7)	265 (6.6)	NA
Low food security	614 (12.0)	649 (11.0)	598 (11.2)	653 (10.1)	525 (12.4)	593 (12.6)	596 (14.8)	529 (14.8)	NA
Marginal food security	393 (7.5)	421 (7.8)	393 (7.8)	462 (8.8)	396 (9.2)	506 (11.3)	526 (13.2)	435 (11.9)	NA
Food secure	2496 (74.0)	2662 (69.1)	2327 (70.0)	2571 (75.0)	1916 (71.5)	1861 (67.6)	1748 (63.8)	1770 (65.7)	NA

(continued)

Table 1. Sociodemographic Characteristics of US Youth Aged 2 to 19 Years by NHANES Survey Cycles From 1999 to 2016 (continued)

Characteristics	No. of participants (survey-weighted %)[a]								
	1999-2000 (n = 3833)	2001-2002 (n = 4288)	2003-2004 (n = 3825)	2005-2006 (n = 4029)	2007-2008 (n = 3109)	2009-2010 (n = 3280)	2011-2012 (n = 3134)	2013-2014 (n = 3021)	2015-2016 (n = 2901)
Federal nutrition program participation[d]									
SNAP	768 (16.7)	805 (14.6)	976 (17.7)	932 (16.2)	911 (21.8)	1121 (23.8)	1229 (31.0)	1076 (27.6)	NA
WIC	839 (16.2)	793 (14.3)	789 (13.6)	818 (13.5)	654 (13.6)	825 (15.4)	705 (17.7)	636 (15.2)	NA
NSLP/SBP	1591 (30.5)	1536 (27.4)	1442 (27.2)	1445 (25.7)	1312 (28.6)	1428 (31.9)	1352 (34.0)	1359 (34.7)	1404 (39.2)

Abbreviations: GED, general equivalency diploma; NA, data not available; NHANES, National Health and Nutrition Examination Survey; NSLP/SPB, reduced-price/free National School Lunch Program/School Breakfast Program; SNAP, Supplemental Nutrition Assistance Program; WIC, Special Supplemental Nutrition Program for Women, Infants, and Children.

[a] Percentages are adjusted for NHANES survey weights.

[b] Ratio of family income to poverty is adjusted for household size; higher numbers indicate higher income.

[c] Data were collected in the food security module by a food security scale questionnaire at the household level during the past 12 months.

[d] These programs are funded by the federal government and administered by states. For SNAP eligibility, a household must meet 3 criteria: (1) household gross monthly income (generally ≤130% of poverty level); (2) household net income after deductions; and (3) household asset limits (generally \$2250, or \$3500 if household includes ≥1 elderly or disabled member). Women are eligible for the WIC if pregnant or having a child up to age 5 years and having a household income ≤180% of poverty level. For the NSLP/SBP, children from households with incomes ≤130% of poverty level are eligible for free meals and children from households with incomes between 130% and 185% of poverty level are eligible for reduced-price meals.

48.5-50.8) out of 100 (an improvement of 11.2%) (*P* < .001 for trend for each). Based on the AHA primary score, the estimated proportion of US youth with poor dietary quality significantly decreased from 76.8% (95% CI, 72.9%-80.2%) to 56.1% (95% CI, 51.4%-60.7%), while the estimated proportion with intermediate quality significantly increased from 23.2% (95% CI, 19.8%-26.9%) to 43.7% (95% CI, 39.1%-48.3%) (*P* < .001 for trend for each). The estimated proportion with an ideal diet significantly improved but remained low (from 0.07% to 0.25%; *P* = .03) (**Figure 1** and eTable 4 in the Supplement). In sensitivity analyses using alternative methods of population ratio and the Markov chain Monte Carlo method for calculating HEI-2015 scores, results were not materially altered (eTables 5 and 6 in the Supplement).

Trends in Specific Foods and Nutrients

Statistically significant changes were found among individual components of the diet scores (**Figure 2**, **Figure 3**, **Table 3**, and eFigure 1 in the Supplement). From 1999 to 2016, the estimated mean consumption of sugar-sweetened beverages significantly decreased from 2.0 to 1.0 servings/d (difference, −1.0 [95% CI, −1.2 to −0.78] servings/d; *P* < .001 for trend) and added sugar from 106 g/d to 71.4 g/d (difference, −34.4 [95% CI, −40.8 to −28.1] g/d; *P* < .001 for trend). The estimated mean consumption of whole grains significantly increased from 0.46 to 0.95 servings/d (difference, +0.50 [95% CI, 0.40-0.59] servings/d), total fruits and vegetables from 1.62 to 1.81 servings/d (difference, +0.19 [95% CI, 0.06-0.32] servings/d), poultry from 0.28 to 0.36 servings/d (difference, +0.07 [95% CI, 0.02-0.12] servings/d), and eggs from 0.25 to 0.39 servings/d (difference, +0.14 [95% CI, 0.10-0.19] servings/d) (*P* < .001 for trend for all). The estimated mean consumption of sodium significantly increased from 3166 mg/d to 3326 mg/d (difference, +160 [95% CI, 74-247] mg/d; *P* < .001 for trend). Intakes of processed meat, refined grains, nuts and seeds, and fish and shellfish did not significantly change.

Among subcomponents of these food groups (Figure 2, Figure 3, and eFigure 1 and eTable 7 in the Supplement), intakes of intact/whole fruit significantly increased from 0.46 to 0.68 servings/d (difference, +0.22 [95% CI, 0.12-0.32] servings/d; *P* < .001 for trend), while 100% fruit juice significantly decreased from 0.63 to 0.46 servings/d (difference, −0.17 [95% CI, −0.27 to −0.07] servings/d; *P* < .001 for trend). Milk significantly decreased from 1.36 to 1.19 servings/d (difference, −0.17 [95% CI, −0.30 to −0.04] servings/d), cheese significantly increased from 0.56 to 0.78 servings/d (difference, +0.21 [95% CI, 0.14-0.29] servings/d), and yogurt significantly increased from 0.03 to 0.06 servings/d (difference, +0.03 [95% CI, 0.02-0.05] servings/d) (*P* < .001 for trend for all).

Among other foods and nutrients, consumption of unprocessed red meat significantly decreased from 0.35 to 0.31 servings/d (difference, −0.04 [95% CI, −0.09 to 0.01] servings/d; *P* = .01 for trend), while processed meat consumption remained stable (*P* = .17 for trend) (Figure 2, Table 3, and eTable 7 in the Supplement). Significant increases were also observed for total fat, with estimated means increasing from 33.2% to 34.5% of energy (difference, +2.34% [95% CI, 1.62%-3.06%] of energy), polyunsaturated

Table 2. Trends in Estimated Scores for Dietary Components of the AHA 2020 Strategic Impact Goals and HEI-2015 Among US Youth Aged 2 to 19 Years by NHANES Survey Cycles From 1999 to 2016

AHA and HEI-2015 scores	Score point range	Scoring extremes		Survey-weighted mean score (95% CI)[a]									*P* value for trend
		Maximum	Minimum	1999-2000 (n = 3833)	2001-2002 (n = 4288)	2003-2004 (n = 3825)	2005-2006 (n = 4029)	2007-2008 (n = 3109)	2009-2010 (n = 3280)	2011-2012 (n = 3132)	2013-2014 (n = 3019)	2015-2016 (n = 2901)	
AHA scores[b]													
Primary score	0-50	50	0	14.8 (14.1-15.4)	15.5 (15.0-16)	15.8 (15.0-16.5)	16.7 (15.7-17.6)	16.6 (15.9-17.3)	17.6 (17.1-18.2)	18.3 (17.8-18.9)	18.6 (17.8-19.3)	18.8 (18.1-19.6)	<.001
Fruits and vegetables[c]	0-10	≥4.5 c equivalents/d	0	3.54 (3.38-3.71)	3.56 (3.36-3.77)	4.03 (3.84-4.23)	4.03 (3.89-4.17)	4.02 (3.79-4.25)	4.19 (3.96-4.43)	4.22 (4.01-4.43)	4.08 (3.93-4.24)	3.96 (3.75-4.17)	<.001
Whole grains	0-10	≥3 oz equivalents/d	0	1.45 (1.26-1.64)	1.68 (1.56-1.80)	1.58 (1.43-1.73)	1.78 (1.53-2.04)	1.88 (1.68-2.08)	2.18 (2.08-2.28)	2.64 (2.46-2.81)	2.81 (2.58-3.04)	3.02 (2.79-3.24)	<.001
Fish and shellfish	0-10	≥2 oz equivalents/d	0	0.73 (0.55-0.91)	0.85 (0.70-0.99)	1.26 (1.07-1.45)	1.36 (1.03-1.69)	1.08 (0.89-1.27)	1.10 (0.84-1.35)	1.17 (0.95-1.40)	1.18 (0.93-1.43)	0.90 (0.74-1.06)	.11
Sugar-sweetened beverages	10-0	≤5.14 fl oz/d	>16 fl oz/d	4.33 (3.89-4.77)	4.70 (4.38-5.03)	4.40 (4.03-4.78)	5.22 (4.83-5.6)	5.43 (5.14-5.71)	6.01 (5.80-6.22)	5.97 (5.72-6.23)	6.47 (6.11-6.84)	6.89 (6.58-7.21)	<.001
Sodium	10-0	≤1500 mg/d	>4500 mg/d	4.70 (4.52-4.89)	4.69 (4.59-4.8)	4.49 (4.38-4.61)	4.26 (4.12-4.41)	4.17 (4.04-4.29)	4.15 (3.99-4.30)	4.34 (4.15-4.52)	4.01 (3.86-4.15)	4.06 (3.93-4.18)	<.001
Secondary score	0-80	80	0	29.2 (28.1-30.4)	30.0 (29.3-30.8)	30.1 (29.2-31.1)	31.3 (29.9-32.6)	31.1 (30.0-32.1)	32.8 (32.1-33.5)	33.4 (32.6-34.3)	33.2 (32.3-34.0)	33.0 (32.0-33.9)	<.001
Nuts, seeds, and legumes	0-10	≥4 servings/wk	0	2.62 (2.36-2.89)	2.48 (2.27-2.69)	3.19 (2.92-3.46)	3.46 (3.11-3.81)	3.20 (2.98-3.41)	3.52 (3.20-3.83)	3.65 (3.38-3.92)	3.20 (2.91-3.49)	3.42 (3.09-3.75)	<.001
Processed meat	10-0	≤0.5 oz/d	>1.764 oz/d	7.21 (6.83-7.58)	7.23 (7.01-7.45)	6.79 (6.6-6.98)	6.94 (6.64-7.24)	6.90 (6.64-7.15)	6.89 (6.63-7.15)	6.71 (6.46-6.96)	6.87 (6.58-7.16)	6.78 (6.51-7.05)	.01
Saturated fat	10-0	≤7% of energy	>15% of energy	4.64 (4.36-4.92)	4.84 (4.64-5.04)	4.39 (4.16-4.61)	4.22 (4.1-4.33)	4.38 (4.18-4.59)	4.76 (4.55-4.97)	4.71 (4.49-4.94)	4.54 (4.33-4.75)	3.92 (3.66-4.18)	.01
HEI-2015 total score[d]	0-100	100	0	44.6 (43.5-45.8)	46.0 (44.9-47.1)	48.5 (47.4-49.6)	47.8 (46.8-48.7)	48.2 (47.1-49.3)	49.6 (48.6-50.5)	51.3 (50.5-52)	49.9 (49.0-50.9)	49.6 (48.5-50.8)	<.001
Adequacy components													
Total fruits[e]	0-5	≥0.8 c equivalents/ 1000 kcal	No fruit	2.30 (2.18-2.41)	2.30 (2.16-2.44)	2.61 (2.42-2.81)	2.75 (2.61-2.89)	2.74 (2.56-2.93)	2.83 (2.67-2.99)	2.90 (2.73-3.06)	2.75 (2.58-2.92)	2.74 (2.58-2.9)	<.001
Whole fruits[f]	0-5	≥0.4 c equivalents/ 1000 kcal	No whole fruit	2.80 (2.67-2.92)	2.85 (2.70-3.00)	3.40 (3.19-3.61)	2.48 (2.34-2.62)	2.56 (2.38-2.74)	2.69 (2.51-2.87)	2.77 (2.59-2.94)	2.72 (2.53-2.90)	2.69 (2.49-2.88)	.005
Total vegetables[g]	0-5	≥1.1 cup equiv. per 1000 kcal	No vegetables	2.28 (2.14-2.42)	2.24 (2.15-2.33)	2.47 (2.39-2.56)	2.31 (2.23-2.40)	2.26 (2.18-2.34)	2.29 (2.21-2.37)	2.28 (2.21-2.36)	2.30 (2.23-2.37)	2.34 (2.24-2.44)	.90
Greens and beans[g]	0-5	≥0.2 c equivalents/ 1000 kcal	No dark-green vegetables or legumes	0.75 (0.64-0.86)	0.71 (0.60-0.82)	0.93 (0.79-1.06)	1.01 (0.88-1.14)	0.98 (0.83-1.13)	1.14 (1.00-1.27)	1.24 (1.10-1.38)	1.26 (1.19-1.33)	1.24 (1.12-1.36)	<.001
Whole grains	0-10	≥1.5 oz equivalents/ 1000 kcal	No whole grains	1.52 (1.32-1.72)	1.72 (1.60-1.84)	1.59 (1.45-1.73)	1.85 (1.60-2.10)	2.0 (1.8-2.19)	2.32 (2.21-2.43)	2.75 (2.57-2.93)	2.97 (2.74-3.21)	3.20 (2.96-3.44)	<.001
Dairy[h]	0-10	≥1.3 c equivalents/ 1000 kcal	No dairy	6.36 (6.08-6.64)	6.73 (6.5-6.96)	7.12 (6.83-7.40)	7.26 (7.09-7.42)	7.16 (6.98-7.35)	7.56 (7.36-7.76)	7.54 (7.32-7.76)	7.33 (7.15-7.50)	6.98 (6.61-7.35)	<.001
Total protein foods[g]	0-5	≥2.5 oz equivalents/ 1000 kcal	No protein foods	3.41 (3.29-3.54)	3.36 (3.28-3.43)	3.77 (3.67-3.87)	3.81 (3.72-3.9)	3.91 (3.85-3.97)	3.88 (3.8-3.97)	3.91 (3.82-4)	3.88 (3.76-4)	3.85 (3.77-3.94)	<.001
Seafood and plant proteins[g,i]	0-5	≥0.8 oz equivalents/ 1000 kcal	No seafood or plant proteins	1.44 (1.29-1.59)	1.47 (1.33-1.60)	1.88 (1.73-2.03)	1.91 (1.67-2.14)	1.77 (1.65-1.88)	1.93 (1.81-2.06)	2.18 (2.06-2.29)	1.91 (1.79-2.03)	1.98 (1.85-2.11)	<.001
Fatty acids[j]	0-10	(PUFAs + MUFAs)/ SFAs ≥2.5	(PUFAs + MUFAs)/ SFAs ≤1.2	3.79 (3.56-4.02)	3.81 (3.65-3.97)	3.58 (3.43-3.73)	3.35 (3.17-3.53)	3.54 (3.39-3.69)	3.74 (3.54-3.95)	4.01 (3.78-4.25)	3.62 (3.38-3.85)	3.64 (3.43-3.84)	.91

(continued)

Table 2. Trends in Estimated Scores for Dietary Components of the AHA 2020 Strategic Impact Goals and HEI-2015 Among US Youth Aged 2 to 19 Years by NHANES Survey Cycles From 1999 to 2016 (continued)

AHA and HEI-2015 scores	Score point range	Scoring extremes		Survey-weighted mean score (95% CI)[a]									P value for trend
		Maximum	Minimum	1999-2000 (n = 3833)	2001-2002 (n = 4288)	2003-2004 (n = 3825)	2005-2006 (n = 4029)	2007-2008 (n = 3109)	2009-2010 (n = 3280)	2011-2012 (n = 3132)	2013-2014 (n = 3019)	2015-2016 (n = 2901)	
Moderation components													
Refined grains	10-0	≤1.8 oz equivalents/ 1000 kcal	≥4.3 oz equivalents/ 1000 kcal	4.98 (4.72-5.24)	4.91 (4.67-5.15)	5.15 (4.9-5.39)	5.19 (4.96-5.43)	5.36 (5.16-5.55)	4.98 (4.80-5.15)	5.15 (4.95-5.34)	5.01 (4.86-5.17)	5.01 (4.80-5.23)	.82
Sodium	10-0	≤1.1 g/1000 kcal	≥2.0 g/1000 kcal	5.28 (5.06-5.49)	5.60 (5.46-5.74)	5.41 (5.24-5.59)	5.15 (4.95-5.35)	5.0 (4.80-5.20)	4.51 (4.27-4.76)	4.79 (4.57-5.01)	4.39 (4.20-4.58)	4.41 (4.23-4.58)	<.001
Added sugars	10-0	≤6.5% of energy	≥26% of energy	4.18 (3.83-4.52)	4.53 (4.34-4.73)	5.10 (4.81-5.39)	5.40 (5.14-5.65)	5.45 (5.26-5.65)	5.90 (5.69-6.11)	5.97 (5.8-6.15)	6.26 (6.04-6.48)	6.64 (6.44-6.85)	<.001
Saturated fats	10-0	≤8% of energy	≥16% of energy	5.56 (5.26-5.86)	5.77 (5.57-5.97)	5.47 (5.23-5.71)	5.29 (5.16-5.42)	5.45 (5.23-5.66)	5.79 (5.59-5.99)	5.79 (5.57-6.01)	5.54 (5.33-5.76)	4.93 (4.65-5.21)	.05

Abbreviations: AHA, American Heart Association; HEI, Healthy Eating Index; MUFA, monounsaturated fatty acid; NHANES, National Health and Nutrition Examination Survey; PUFA, polyunsaturated fatty acid; SFA, saturated fatty acid.

[a] Data were weighted to be nationally representative. Higher scores indicate greater adherence to the AHA 2020 dietary Strategic Impact Goals or the 2015 *Dietary Guidelines for Americans*.

[b] Dietary components associated with AHA scores were adjusted for energy to 2000 kcal/d using the residual method prior to analysis. Each AHA consumption target was evaluated based on a continuous scoring system. Intake of each dietary component was scored from 0 to 10 (higher scores indicating higher consumption of beneficial components) and from 10 to 0 (higher scores indicating lower consumption of harmful components). For beneficial dietary components, individuals with zero intake received a score of 0. Intermediate dietary intake was scored linearly between 0 and 10. The primary total diet score is the sum of the scores for the 5 dietary components included in the primary score. The secondary total diet score is the sum of the score for all 8 components included in the primary and secondary scores.

[c] According to the AHA 2020 Strategic Impact Goals, up to 3 c/wk (0.42 c/d) of starchy vegetables (eg, potatoes, peas, corn) could be included; this maximum was incorporated into the analysis, with higher intake not contributing toward the score. Consumption of 100% fruit juice could also be included; however, its contribution was not capped in the original AHA 2020 Strategic Impact Goals and not in our score. Some organizations recommend no more than 1 serving/d of 100% fruit juice.

[d] The HEI-2015 total diet score is the sum of the scores for the 9 dietary components included in adequacy components and 4 dietary components included in moderation components. Intakes between the minimum and maximum standards were scored proportionately.

[e] Includes 100% fruit juice.

[f] Includes all forms except juice.

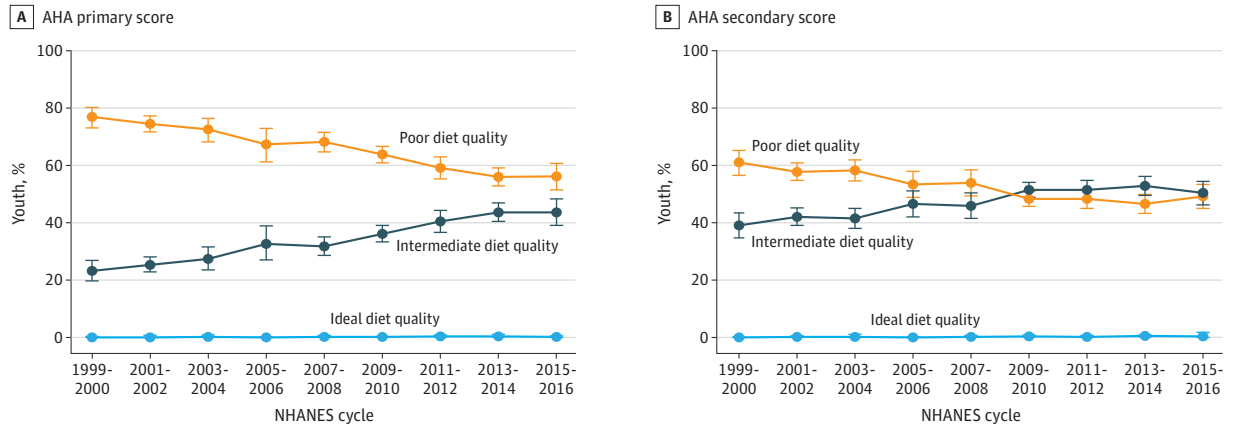
[g] Includes legumes (beans and peas).

[h] Includes all milk products, such as fluid milk, yogurt, and cheese, and fortified soy beverages.

[i] Includes seafood, nuts, seeds, soy products (other than beverages), and legumes (beans and peas).

[j] Ratio of PUFAs and MUFAs to SFAs.

Figure 1. Trends in Estimated Proportions of US Youth Aged 2 to 19 Years With Poor, Intermediate, or Ideal Diet Quality



Trends are according to the American Heart Association (AHA) 2020 Strategic Impact Goals, based on a continuous scoring system by National Health and Nutrition Examination Survey (NHANES) cycles from 1999-2000 to 2015-2016. The primary score is based on total fruits and vegetables, whole grains, fish and shellfish, sugar-sweetened beverages, and sodium, and the secondary score further adds nuts, seeds, and legumes, processed meat, and saturated fat. Data were weighted to be nationally representative. Data points indicate estimated percentages; error bars, 95% CIs. For dietary quality based on the AHA primary score, $P < .001$ for trend for poor (decrease) and intermediate (increase) quality and $P = .03$ for ideal quality (increase). For dietary quality based on the AHA secondary score, $P < .001$ for trend for poor (decrease) and intermediate (increase) quality and $P = .03$ for ideal quality (increase).

fat from 6.17% to 7.58% of energy (difference, +1.41% [95% CI, 1.23%-1.58%] of energy), and protein from 13.4% to 14.8% of energy (difference, +1.29% [95% CI, 0.90%-1.69%] of energy) ($P < .001$ for trend for all). The estimated mean consumption of total carbohydrate significantly decreased from 55.4% to 51.9% of energy (difference, −3.52% [95% CI, −4.34% to −2.69%] of energy; $P < .001$ for trend). The estimated mean consumption of plant omega-3 fat significantly increased from 116 mg/d to 146 mg/d (difference, +29.7 [95% CI, 24.9-34.6] mg/d; $P < .001$ for trend), whereas the estimated mean consumption of seafood omega-3 fat significantly decreased from 51 mg/d to 42.3 mg/d (difference, −8.74 [95% CI, −19.8 to 2.33] mg/d; $P = .002$ for trend). Other significant increases were identified for dietary cholesterol from 218 mg/d to 254 mg/d (difference, +36.0 [95% CI, 24.8-47.2] mg/d), fiber from 12.4 mg/d to 15.6 mg/d (difference, +3.14 [95% CI, 2.53-3.76] mg/d), and calcium from 875 mg/d to 1061 mg/d (difference, +186 [95% CI, 132-240] mg/d) ($P < .001$ for trend for all).

In sensitivity analyses, the findings for most dietary components were not materially altered by adjustment for sociodemographic shifts in age, sex, and race/ethnicity over time (eTable 8 in the Supplement). Exceptions included legumes, in which observed increases were partially attenuated (by 53.2%) by these adjustments, total dairy (increased further by 14.7%), and unprocessed red meat (increased further by 13.7%).

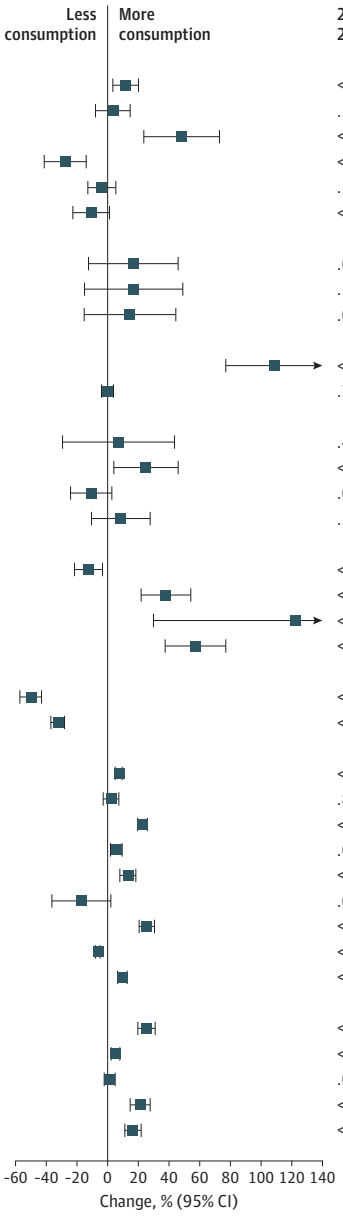
Trends in Population Subgroups

From 1999 to 2016, significant improvements in diet quality were observed among all subgroups, but with mostly persistent or increasing differences based on mean dietary scores (eTables 9 and 10 in the Supplement) or proportions having poor, intermediate, or ideal diet quality (eTables 11 and 12 in the Supplement). For example, while diet quality significantly improved in all age groups, the estimated proportion of youth having poor diet quality in 2015-2016 was 39.8% (95% CI, 35.1%-44.5%) for ages 2 to 5 years, 52.5% (95% CI, 46.4%-58.5%) for ages 6 to 11 years, and 66.6% (95% CI, 61.4%-71.4%) for ages 12 to 19 years ($P < .001$ for differences by age in 2015-2016). Similarly, while diet quality improved over time among youth with higher or lower parental education, household income, or household food security status, the estimated proportion with poor diet quality in 2015-2016 was 64.5% (95% CI, 59.5%-69.1%) among youth with household income less than 1.30 times the poverty level and 47.2% (95% CI, 39.4%-55.3%) among youth with household income of at least 3.00 times the poverty level ($P = .02$ for differences by income in 2015-2016), with similar differences across levels of parental education or household food security status. In contrast, the estimated proportions of youth having poor diet quality in 2015-2016 were statistically nonsignificant among youth participating or not participating in SNAP (yes: 59.8% [95% CI, 54.7%-64.7%]; no: 54.4% [95% CI, 50.4%-58.4%]) or WIC (yes: 54.4% [95% CI, 46.9%-61.8%]; no: 56.2% [95% CI, 52.6%-59.7%]).

Trends in individual food groups and nutrients according to population subgroups are shown in eFigures 2 through 7 and eTables 13 through 21 in the Supplement. Dietary factors with notable population subgroup differences in trends over time included refined grains, sugar-sweetened beverages, white potatoes, processed meat, fruit juice, whole fruit, nuts and seeds, and sodium. For example, the estimated mean consumption of refined grains significantly increased from 6.22 servings/d (95% CI, 6.10-6.34 servings/d) to 6.60 servings/d (95% CI, 6.45-6.75 servings/d) among Mexican American youth ($P < .001$ for trend) but remained stable among non-Hispanic white and non-Hispanic black youth ($P < .001$ for interaction). Intakes of sugar-sweetened beverages significantly decreased across all

Figure 2. Changes in Estimated Mean Consumption of Dietary Components Among US Youth Aged 2 to 19 Years

Foods/nutrients	Change, % (95% CI)	*P* value for trend, 1999-2000 to 2015-2016
Fruits and vegetables		
Total fruits and vegetables	11.7 (3.31 to 20.1)	<.001
All fruits	3.40 (-7.99 to 14.8)	.12
Whole fruits	48.3 (23.6 to 73.0)	<.001
100% fruit juice	-27.7 (-41.4 to -13.9)	<.001
Vegetables excluding potatoes	-3.79 (-12.9 to 5.28)	.13
White potatoes	-10.8 (-22.7 to 1.22)	<.001
Nuts, seeds, and legumes		
Total nuts, seeds, and legumes	-16.8 (-12.0 to 46.0)	.06
Nuts and seeds	17.0 (-15.0 to 49.0)	.11
Legumes	-14.6 (-15.0 to 44.5)	.02
Grains		
Whole grains	109 (77.0 to 141)	<.001
Refined grains	-0.003 (-3.94 to 3.94)	.75
Meats and fish		
Fish and shellfish	7.10 (-29.0 to 43.6)	.47
Poultry	25.0 (3.98 to 46.0)	<.001
Unprocessed red meat	-10.6 (-24.1 to 2.83)	.01
Processed meat	8.63 (-10.4 to 27.7)	.17
Dairy and eggs		
Milk	-12.5 (-21.6 to -3.37)	<.001
Cheese	38.0 (21.9 to 54.2)	<.001
Yogurt	122 (29.8 to 214.7)	<.001
Eggs	57.2 (37.4 to 77.0)	<.001
Sugars		
Sugar-sweetened beverages	-50.0 (-57.1 to -43.0)	<.001
Added sugar	-32.5 (-36.9 to -28.1)	<.001
Macronutrients		
Total fat	7.28 (4.96 to 9.60)	<.001
Monosaturated fat	2.17 (-2.99 to 7.34)	.82
Polyunsaturated fat	22.8 (19.5 to 26.1)	<.001
Saturated fat	5.66 (1.90 to 9.42)	.047
Ratio of polyunsaturated fat to saturated fat	13.2 (7.90 to 18.4)	<.001
Seafood omega-3 fat	-17.2 (-36.3 to 2.02)	.002
Plant omega-3 fat	25.6 (20.6 to 30.9)	<.001
Carbohydrates	-6.35 (-7.78 to -4.93)	<.001
Protein	9.62 (6.47 to 12.8)	<.001
Other key nutrients		
Fiber	25.3 (19.6 to 30.9)	<.001
Sodium	5.07 (2.25 to 7.89)	<.001
Potassium	1.35 (-2.17 to 4.88)	.001
Calcium	21.2 (14.6 to 27.8)	<.001
Cholesterol	16.5 (11.1 to 21.9)	<.001



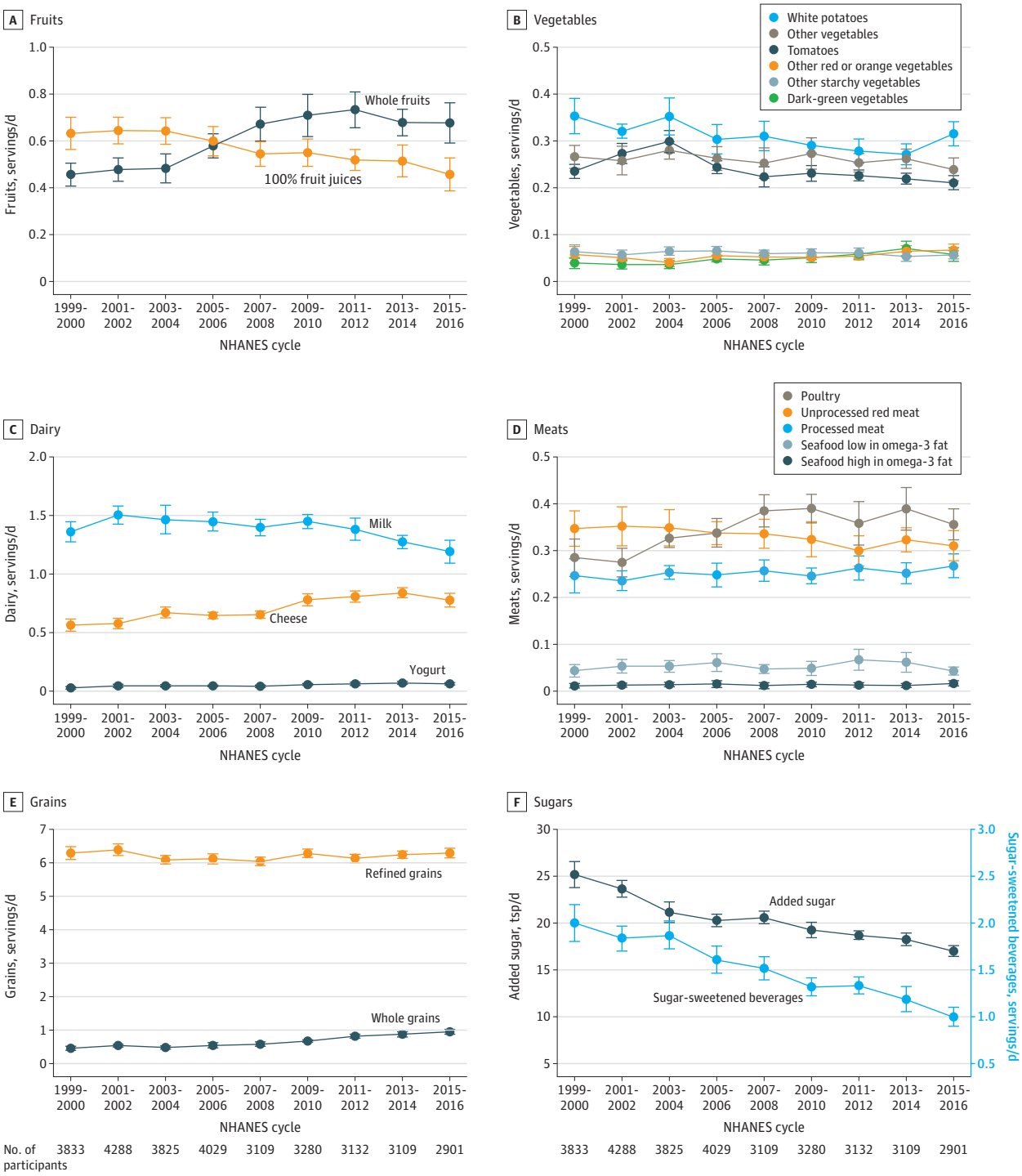
Based on National Health and Nutrition Examination Survey (NHANES) data from 1999-2000 to 2015-2016. Data represent estimated mean change in population dietary intake from 1999-2000 to 2015-2016. The analyses were based on energy-adjusted values to 2000 kcal/d using the residual method. *P* values for trend were estimated across all NHANES cycles from 1999 to 2016.

subgroups but with larger decreases among youth aged 12 to 19 years, males, and youth not participating in federal food assistance programs ($P \le .01$ for interaction for all). Increases in whole fruit were larger among youth not participating in reduced-price/free school nutrition programs ($P = .005$ for interaction), while fruit juice intake decreased more among females than males and among those with higher vs lower parental education level ($P < .05$ for interaction for each). Nuts and seeds increased more among youth aged 12 to 19 years; those with higher parental education, household income, or food security; and those not participating in federal food assistance programs ($P < .05$ for interaction for each).

Discussion

From 1999 to 2016, overall dietary quality improved among US youth, associated with increased consumption of fruits and vegetables (especially whole fruits) and whole grains, with additional increases in total dairy, total protein foods, seafood, and plant proteins and decreased consumption of sugar-sweetened beverages and added sugar. Based on the different validated dietary scores, mean dietary quality improved by 11.2% to 27.0%. The proportion of US youth with poor diets decreased substantially (from 71.8% to 54.4%),

Figure 3. Trends in Estimated Mean Consumption of Key Food Groups and Nutrients Among US Youth Aged 2 to 19 Years by NHANES Cycles From 1999-2000 to 2015-2016



Data are weighted to be nationally representative. Data points indicate estimated means; error bars, 95% CIs. Added sugar: 1 tsp = 4.2 g. Analyses were based on energy-adjusted values to 2000 kcal/d using the residual method. $P < .001$ for trend for whole fruits (increase), 100% fruit juices (decrease), white potatoes (decrease), tomatoes (decrease), dark-green vegetables (increase), milk (decrease), cheese (increase), yogurt (increase), poultry (increase), whole grains (increase), sugar-sweetened beverages (decrease), and added sugar (decrease). Other significant trends were observed for other red or orange vegetables (increase; $P = .03$ for trend) and unprocessed red meat (decrease; $P = .01$ for trend). Trends for the remaining dietary components remained stable.

Table 3. Trends in Estimated Mean Consumption of Key Dietary Components Among US Youth Aged 2 to 19 Years by NHANES Survey Cycles From 1999 to 2016

Dietary factors	Survey-weighted mean (95% CI)[a]									*P* value for trend	Difference, 2015-2016 vs 1999-2000 (95% CI)
	1999-2000 (n = 3833)	2001-2002 (n = 4288)	2003-2004 (n = 3825)	2005-2006 (n = 4029)	2007-2008 (n = 3109)	2009-2010 (n = 3280)	2011-2012 (n = 3132)	2013-2014 (n = 3019)	2015-2016 (n = 2901)		
AHA primary component goals											
Fruits and vegetables, servings/d	1.62 (1.54-1.69)	1.65 (1.56-1.75)	1.83 (1.74-1.92)	1.83 (1.76-1.9)	1.84 (1.73-1.95)	1.93 (1.80-2.05)	1.93 (1.83-2.03)	1.86 (1.79-1.94)	1.81 (1.70-1.91)	<.001	0.19 (0.06 to 0.32)
Whole grains, servings/d	0.46 (0.39-0.52)	0.54 (0.49-0.58)	0.48 (0.43-0.53)	0.55 (0.47-0.63)	0.58 (0.51-0.65)	0.67 (0.64-0.71)	0.82 (0.76-0.88)	0.87 (0.79-0.95)	0.95 (0.88-1.03)	<.001	0.50 (0.40 to 0.59)
Fish and shellfish, servings/d	0.06 (0.04-0.07)	0.07 (0.05-0.08)	0.07 (0.05-0.08)	0.08 (0.05-0.10)	0.06 (0.05-0.07)	0.06 (0.05-0.08)	0.08 (0.06-0.10)	0.07 (0.05-0.10)	0.06 (0.05-0.07)	.47	0.004 (−0.02 to 0.02)
Sugar-sweetened beverages, servings/d	2.00 (1.80-2.20)	1.83 (1.70-1.97)	1.87 (1.72-2.03)	1.61 (1.46-1.76)	1.52 (1.39-1.64)	1.32 (1.22-1.42)	1.33 (1.24-1.43)	1.19 (1.05-1.32)	1.00 (0.90-1.10)	<.001	−1.0 (−1.22 to −0.78)
Sodium, mg/d	3166 (3089-3242)	3148 (3111-3184)	3193 (3154-3232)	3263 (3205-3322)	3302 (3261-3343)	3307 (3252-3362)	3241 (3180-3303)	3387 (3287-3486)	3326 (3285-3367)	<.001	160 (73.8 to 247)
AHA secondary component goals											
Nuts, seeds, and legumes, servings/d	0.37 (0.30-0.45)	0.34 (0.28-0.39)	0.38 (0.32-0.44)	0.39 (0.34-0.44)	0.39 (0.34-0.43)	0.41 (0.35-0.47)	0.43 (0.36-0.49)	0.37 (0.33-0.42)	0.44 (0.38-0.50)	.06	0.06 (−0.04 to 0.16)
Processed meat, servings/d	0.25 (0.21-0.28)	0.24 (0.21-0.26)	0.25 (0.24-0.27)	0.25 (0.22-0.27)	0.26 (0.23-0.28)	0.25 (0.23-0.26)	0.26 (0.24-0.29)	0.25 (0.23-0.27)	0.27 (0.24-0.29)	.17	0.02 (−0.02 to 0.07)
Saturated fat, % of energy	11.5 (11.2-11.8)	11.3 (11.1-11.5)	11.6 (11.4-11.8)	11.8 (11.7-11.9)	11.6 (11.4-11.8)	11.3 (11.1-11.5)	11.3 (11.1-11.5)	11.5 (11.3-11.7)	12.1 (11.9-12.4)	.05	0.65 (0.23 to 1.07)
HEI-2015 components[b]											
Total fruits, servings/d	1.01 (0.93-1.09)	1.05 (0.96-1.14)	1.07 (0.97-1.17)	1.09 (1.03-1.16)	1.11 (1.01-1.21)	1.16 (1.05-1.26)	1.19 (1.10-1.28)	1.08 (1.00-1.17)	1.04 (0.96-1.13)	.12	0.03 (−0.08 to 0.15)
Intact/whole fruit, servings/d	0.46 (0.41-0.51)	0.48 (0.43-0.53)	0.48 (0.42-0.55)	0.58 (0.53-0.63)	0.67 (0.60-0.75)	0.71 (0.62-0.80)	0.73 (0.66-0.81)	0.68 (0.62-0.74)	0.68 (0.59-0.76)	<.001	0.22 (0.12 to 0.32)
Total vegetables, servings/d	1.02 (0.95-1.09)	1.00 (0.96-1.04)	1.08 (1.03-1.13)	0.99 (0.95-1.03)	0.97 (0.91-1.02)	0.98 (0.93-1.03)	0.95 (0.91-0.99)	0.98 (0.93-1.02)	0.98 (0.94-1.02)	.02	−0.04 (−0.12 to 0.04)
Dark-green vegetables, servings/d	0.04 (0.03-0.05)	0.04 (0.03-0.05)	0.04 (0.03-0.04)	0.05 (0.04-0.05)	0.05 (0.04-0.06)	0.05 (0.04-0.06)	0.06 (0.05-0.07)	0.07 (0.06-0.09)	0.06 (0.04-0.07)	<.001	0.02 (0 to 0.04)
Legumes, servings/d	0.07 (0.05-0.08)	0.06 (0.05-0.07)	0.06 (0.05-0.08)	0.06 (0.04-0.07)	0.06 (0.04-0.07)	0.07 (0.06-0.08)	0.07 (0.06-0.09)	0.07 (0.06-0.08)	0.08 (0.06-0.09)	.02	0.01 (−0.009 to 0.03)
Refined grains, servings/d	6.29 (6.09-6.49)	6.39 (6.22-6.57)	6.09 (5.96-6.22)	6.12 (5.97-6.27)	6.04 (5.92-6.17)	6.28 (6.16-6.41)	6.13 (6.01-6.26)	6.24 (6.14-6.35)	6.29 (6.14-6.44)	.75	0 (−0.25 to 0.25)
Total dairy, servings/d	1.99 (1.88-2.10)	2.18 (2.08-2.27)	2.22 (2.09-2.36)	2.20 (2.13-2.28)	2.19 (2.11-2.27)	2.38 (2.30-2.46)	2.35 (2.23-2.46)	2.29 (2.19-2.39)	2.13 (1.98-2.28)	.005	0.14 (−0.04 to 0.33)
Unprocessed red meat, servings/d	0.35 (0.31-0.39)	0.35 (0.31-0.39)	0.35 (0.31-0.39)	0.34 (0.31-0.36)	0.34 (0.30-0.37)	0.32 (0.29-0.36)	0.30 (0.27-0.33)	0.32 (0.30-0.35)	0.31 (0.28-0.34)	.01	−0.04 (−0.09 to 0.01)
Poultry, servings/d	0.28 (0.24-0.33)	0.27 (0.24-0.31)	0.33 (0.31-0.35)	0.34 (0.31-0.37)	0.38 (0.35-0.42)	0.39 (0.36-0.42)	0.36 (0.31-0.41)	0.39 (0.34-0.44)	0.36 (0.32-0.39)	<.001	0.07 (0.02 to 0.12)
Eggs, servings/d	0.25 (0.23-0.27)	0.29 (0.25-0.32)	0.30 (0.26-0.33)	0.35 (0.33-0.38)	0.37 (0.34-0.41)	0.36 (0.32-0.4)	0.36 (0.32-0.39)	0.36 (0.34-0.38)	0.39 (0.36-0.43)	<.001	0.14 (0.10 to 0.19)
Nuts and seeds, servings/d	0.34 (0.26-0.42)	0.31 (0.25-0.36)	0.35 (0.29-0.41)	0.36 (0.31-0.41)	0.36 (0.31-0.40)	0.37 (0.31-0.43)	0.39 (0.32-0.46)	0.34 (0.29-0.39)	0.40 (0.34-0.46)	.11	0.06 (−0.04 to 0.16)

(continued)

Table 3. Trends in Estimated Mean Consumption of Key Dietary Components Among US Youth Aged 2 to 19 Years by NHANES Survey Cycles From 1999 to 2016 (continued)

Dietary factors	Survey-weighted mean (95% CI)[a] 1999-2000 (n = 3833)	2001-2002 (n = 4288)	2003-2004 (n = 3825)	2005-2006 (n = 4029)	2007-2008 (n = 3109)	2009-2010 (n = 3280)	2011-2012 (n = 3132)	2013-2014 (n = 3019)	2015-2016 (n = 2901)	*P* value for trend	Difference, 2015-2016 vs 1999-2000 (95% CI)
Soy, servings/d	0.01 (0.008-0.02)	0.03 (0.02-0.04)	0.04 (0.03-0.05)	0.02 (0.02-0.03)	0.03 (0.02-0.04)	0.04 (0.03-0.04)	0.06 (0.05-0.07)	0.05 (0.03-0.06)	0.05 (0.04-0.07)	<.001	0.04 (0.03 to 0.05)
Seafood high in omega-3, servings/d	0.01 (0.007-0.02)	0.01 (0.009-0.02)	0.01 (0.009-0.02)	0.02 (0.008-0.02)	0.01 (0.005-0.02)	0.01 (0.01-0.02)	0.01 (0.009-0.02)	0.01 (0.008-0.02)	0.02 (0.01-0.02)	.45	0.005 (−0.002 to 0.01)
Seafood low in omega-3, servings/d	0.04 (0.03-0.06)	0.05 (0.04-0.07)	0.05 (0.04-0.07)	0.06 (0.04-0.08)	0.05 (0.04-0.06)	0.05 (0.03-0.06)	0.07 (0.04-0.09)	0.06 (0.04-0.08)	0.04 (0.03-0.05)	.54	−0.001 (−0.02 to 0.02)
Polyunsaturated fat, % of energy	6.17 (6.03-6.32)	5.94 (5.80-6.09)	6.46 (6.35-6.56)	6.41 (6.23-6.59)	6.53 (6.43-6.64)	6.84 (6.72-6.97)	7.41 (7.28-7.55)	7.29 (7.10-7.47)	7.58 (7.47-7.69)	<.001	1.41 (1.23 to 1.58)
Monounsaturated fat, % of energy	14.8 (14.2-15.3)	14.5 (13.9-15.0)	13.4 (12.8-14.0)	14.0 (13.5-14.4)	15.0 (14.6-15.4)	13.7 (13.3-14.1)	13.4 (13.1-13.8)	13.9 (13.5-14.4)	15.1 (14.6-15.6)	.82	0.32 (−0.44 to 10.1)
Added sugar, g/d	106 (99.9-112)	99.4 (95.7-103)	88.9 (84.2-93.6)	85.2 (82.4-88.0)	86.6 (83.7-89.4)	80.9 (77.5-84.3)	78.5 (76.5-80.5)	76.7 (73.9-79.6)	71.4 (69.0-73.9)	<.001	−8.18 (−9.70 to −6.66)

Abbreviation: AHA, American Heart Association; HEI, Healthy Eating Index; NHANES, National Health and Nutrition Examination Survey.

[a] Data are weighted to be nationally representative. The majority of means were adjusted for energy to 2000 kcal/d using the residual method. The means for saturated fat, monounsaturated fat, and polyunsaturated fat were adjusted as a percentage of total energy.

[b] The HEI-2015 components are disaggregated into separate parts. For example, greens and beans are presented separately as dark-green vegetables and legumes. Total protein foods are presented as poultry, processed meat, unprocessed red meat, seafood, soy, and nuts and seeds. Components such as processed meat, saturated fat, and sodium that are covered by the AHA are not presented again under the HEI components (eTables 3 and 4 in the Supplement).

with these youth shifting to diets that were intermediate but not ideal in quality. Yet overall diet quality remained low, with more than half of US youth still having a poor diet. Significant trends were not identified for consumption of total vegetables, fish and shellfish, processed meats, or refined grains, and statistically significant but small changes were observed for other food components.

Dietary sodium increased and greatly exceeded the 2019 National Academies of Sciences, Engineering, and Medicine dietary reference intake of 2300 mg/d,[21] which may relate to steadily increasing consumption of processed foods and food prepared away from home.[22,23] These findings support the need for reactivating the currently suspended long-term US Food and Drug Administration voluntary sodium targets and timelines for reducing sodium in packaged foods and restaurant foods.[24]

Persistent differences in overall diet quality were identified by major population sociodemographic factors, with little evidence for declining differences during this 18-year period and some increasing differences for certain foods. For example, compared with younger children, older youth had persistently worse diet quality (with an estimated 66.6% of adolescents having poor diet quality in 2015-2016), consistent with increased marketing, availability, and/or selection of less healthy foods at older ages. Similar persistent differences were identified by parental education, household income, and household food security status. Differences in diet quality were much smaller by participation in SNAP or WIC. These results support the need for continued efforts from federal and local governments, nonprofit organizations, and industry to improve diet quality among all sectors of US youth.[25,26]

Prior analyses of diets among US youth generally assessed a limited number of factors,[12,14,22,27] with few reporting on overall diet quality.[15,28,29] A study assessing trends in HEI-2010 among US youth through 2012[12] identified modest improvements overall and in component scores for whole fruits, whole grains, dairy, total protein foods, sugar-sweetened beverages, and added sugar. These findings build on and extend previous reports by assessing dietary trends through 2016, evaluating several diet quality scores and diverse individual foods and nutrients, and assessing differences in trends according to multiple sociodemographic factors. Compared with recent analyses among US adults,[17,30] some similarities and differences are evident. Similar to the present findings for youth, overall diet quality among US adults slowly improved, mainly because of increased whole grains and decreased sugar-sweetened beverages and added sugar; yet large proportions continued to have poor diet quality, with persistent or increasing differences among key sociodemographic subgroups.[17] Adults, but not children, exhibited increased consumption of nuts and seeds and fish and shellfish and decreased consumption of refined grains.[17] These results highlight the need for future research to illuminate the reasons for both similarities and differences in dietary trends in US children vs adults.

Several of the changes in mean daily servings were modest, yet such small changes in daily intake may sum to more

meaningful changes in weekly, monthly, or yearly consumption. In addition, small mean changes across an entire population can influence the overall exposure distribution and corresponding risk in that population.[31] Consistent with this, the modest changes in mean intake of individual foods led to meaningful changes in the estimated proportions of US youth consuming poor vs intermediate diets. While diets later in life are linked to many major health outcomes, determining these relationships in youth is more challenging, given their low absolute risk of disease. The strongest evidence is generally for childhood overweight and obesity linked to intakes of sugar-sweetened beverages and ultraprocessed foods.[32] The findings of modest overall dietary improvements but persistent poor diets among the majority of children and adolescents are consistent with the slowing or potential plateauing, but not reversing, of obesity rates among US youth.[33] Because dietary habits in earlier life influence habits in adulthood,[2,34] these findings suggest potential long-term benefits of the modest observed improvements in diet quality as well as major continuing concerns for the large numbers of youth with poor diets and the enduring differences by sociodemographic factors.

During the period of this study, 3 iterations of the *Dietary Guidelines for Americans* progressively focused on healthy foods and diet patterns rather than isolated nutrient targets[35]; the White House Let's Move program focused on healthier eating and physical activity in children[36]; the Child Nutrition Act improved and strengthened child nutrition programs[3]; and the Healthy, Hunger-Free Kids Act set more rigorous nutrition standards for school meals and competitive foods.[4] Advocacy organizations like the American Academy of Pediatrics and the AHA promoted fruits, vegetables, and whole grains and avoidance of sugar-sweetened beverages and added sugar.[18,37] Industry also reduced added sugar in beverages, stimulated by both market demand and voluntary targets. Other national actions, which may be too recent to have significantly influenced the observed trends through 2015-2016, include passage of the SNAP FINI (now GusNIP) program in 2014[9] and implementation of sugar-sweetened beverage taxes and proposed warning labels in several US localities.[38] The findings support the need for rigorous evaluation of national and community strategies to improve diet quality to identify the most influential actions.

Limitations

This study has several limitations. First, self-reported dietary information is subject to random and systematic error. Yet interview-administered 24-hour recalls using computer-assisted personal interview system were used; results were further adjusted for total energy, each of which reduce measurement error; and random error does not bias population or stratum-specific mean intakes. Second, no single metric of diet quality is established. However, the results were generally consistent among 2 AHA diet scores and the HEI-2015 score. Third, methodologic changes over time in NHANES data collection and food and nutrition databases might influence the estimated trends. Such effects were minimized by pairing each NHANES cycle with the corresponding "What We Eat in America" database. Fourth, the cross-sectional nature of each NHANES cycle does not allow direct evaluation of changes in diet among individuals, only of national dietary trends. Fifth, although these dietary scores have been validated against clinical outcomes in diverse adult populations,[39] their potential clinical relevance among youth may not be generalizable and requires validation against clinical outcomes relevant to youth. Sixth, even though these may be the most recent data available, it is uncertain whether the findings observed are applicable to diet quality among youth in 2020.

Conclusions

Based on serial NHANES surveys from 1999 to 2016, the estimated overall diet quality of US youth showed modest improvement, but more than half of youth still had poor-quality diets.

ARTICLE INFORMATION

Author Contributions: Dr Liu had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: Liu, Rehm, Mozaffarian.
Acquisition, analysis, or interpretation of data: All authors.
Drafting of the manuscript: Liu, Rehm, Onopa.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Liu, Rehm.
Obtained funding: Liu, Mozaffarian.
Administrative, technical, or material support: Onopa.
Supervision: Rehm, Mozaffarian.

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