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Trends in body mass index, obesity and overweight among adults in the United States, NHANES 2003 to 2018

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Trends in body mass index, obesity and overweight among adults in the United States, NHANES 2003 to 2018

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Abstract

Objectives: To analyze detailed trends in adult obesity from 2003 through 2018, and provide latest national estimates of adult obesity 2017-2018.

Design, Setting and Participants: Analysis of data including measured height and weight obtained from 42,266 adults aged ≥ 20 years in the National Health and Nutrition Examination Survey, a cross-sectional, nationally representative sample of the US population.

Exposure: Survey period.

Primary Outcome Measures: The mean body mass index and the prevalence of obesity and overweight.

Results: In 2017-2018, the weighted mean(SE) body mass index was 29.75±0.27 kg/m^2 for men and 29.96±0.37 kg/m^2 for women. The prevalence of obesity (body mass index ≥ 30 kg/m^2) was 43.3% (95% CI, 38.2%-48.4%) among men and 42.3% (95% CI, 38.6%-46.0%) among women. Over the 16-year period from 2003-2004 through 2017-2018, a significant increase of mean body mass index was found among both men and women (overall adjusted beta for 2017-2018 vs 2003-2004, 1.96 [95% CI, 1.34-2.57]). From 2003-2004 through 2017-2018, trends in obesity prevalence increased significantly among both men and women (overall adjusted odds ratio for 2017-2018 vs 2003-2004, 1.15 [95% CI, 1.10-1.21]). However, annual changes in mean body mass index, prevalence of obesity and overweight did not differ significantly before and after 2009-2010.

Conclusions: Although the prevalence of adult obesity continues to rise, there have been no significant changes in rising rate of adult obesity prevalence between 2003-2004 and 2017-2018. In 2017-2018, the prevalence of obesity was 43.3% among adult men and 42.3% among adult women.

Keywords: American adults; body mass index; obesity/overweight; trends; NHANES

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Strengths and limitations of this study

1.Our present study used a larger sample size as well as a longer time span.

2. Our study assessed annual change in BMI and obesity, and the potential effects of financial crisis around 2009 among US adults.

3. Obesity was defined mainly based on measurements of BMI, which does not measure body fat directly.

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1. Introduction

Obesity is one of most common risk factor for chronic diseases such as diabetes mellitus, cardiovascular diseases, renal damage and cancers that affects 670 million adults globally in 2016[1-7]. In the United States, obesity rates has been on the rise since the 1980s[8]. By 2030, obesity is expected to reach a prevalence of 48.9% among American adults[9].

Some studies have reported on trends in obesity prevalence among American adults using the National Health and Nutrition Examination Survey (NHANES) data[8 10-19]. Between 1976-1980 and 1988-1994, obesity prevalence among American adults increased from 14.5% to 22.5%[10]. The prevalence of obesity increasing from 22.9% to 30.5% form 1988-1994 through 1999-2000, maintaining similar growth rates of about 8%[11]. Over the period 1999-2000 to 2017-2018, there were larger changes in the prevalence among men (from 27.5% to 43.0%) than seen previously and similar growth in prevalence among women (from 33.4% to 41.9%).[14] Most of the previous studies focused on differences in prevalence of obesity by age, sex and race. The differences in prevalence of obesity by other covariates such as educational status, economic status, physical activity status have been scarcely studied.

In this study, we aimed to provide the latest national estimates of adult obesity and evaluate trends in mean body mass index(BMI) and adult obesity between 2003-2004 and 2017-2018. We also focus on the changes of mean BMI and adult obesity before and after 2009 (The 2008–2009 global financial crisis taken place). In addition, we assess how these trends might vary by age, sex, race, educational status, economic status and physical activity status.

2. Materials and methods

2.1 Database and participants

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The NHANES is a nationally representative sample of United States population, which collects data from survey participants through household interviews, standardized physical examinations, and laboratory tests in mobile examination centers[20]. The NHANES released data every 2 years to ensure adequate sample size for analyses and protect confidentiality. Detailed information on the NHANES procedures is available in the literature.[21]

The present study used NHANES data including adults aged ≥ 20 years (N = 44,790) collected between 2003-2004 and 2017-2018 with 8 survey cycles. Among the 44,790 participants (21,668 men and 23,122 women), 42,266 had complete data on BMI, who were included in the final analysis.

2.2 Data collection

Information about anthropometric measurements (including height and weight) and BMI was obtained from examination data. Information about age, sex, race, education, poverty income ratio (PIR) was obtained from demographics data. Data on total energy intake was obtained from the total nutrient intakes file (second day dietary interview), which contains a summary of an individual's nutrition from all foods and beverages provided on the dietary recall. PIR was a ratio of family income to poverty threshold, which was calculated by dividing family income by the poverty guidelines for the survey year. PIR was categorized into two groups: <130% and ≥ 130%. This classification of PIR has been used in a previous study.[22] Data on physical activity was obtained from through the physical activity questionnaire. Based on the 2018 Physical Activity Guidelines for Americans, respondents who engaged in moderate-intensity aerobic activity for 150 min/week or vigorous-intensity aerobic activity for 75 min/week, or an equivalent combination of both (1 min of vigorous-intensity physical activity is equivalent to 2 min of moderate intensity physical activity) were defined as meeting the guidelines.[23] In our analysis, physical activity was categorized into three levels: sufficiently active,

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insufficiently active and inactive. Sufficiently active was defined as moderate-intensity aerobic activity for 150 min/week or vigorous-intensity aerobic activity for 75 min/week, or an equivalent combination of both. Insufficiently active was defined as some aerobic activity but not enough to meet the guidelines(10-149 min/week). Inactive was defined as some physical activity (< 10 min/week) or reported no physical activity.[23] This classification of physical activity has been used in previous studies.[24]

2.3 Statistical analysis

According to WHO classification, we defined obesity as BMI ≥ 30 kg/m^2 and overweight as BMI ≥ 25 kg/m^2. Overall, the mean BMI and prevalence of obesity and overweight in each survey cycle were calculated incorporating sample weights and adjusted for clusters and strata of the complex sample design of the NHANES. Individuals with missing demographic information on height or weight measurements are excluded from the analyses.

In table 1, continuous variables were presented as weighted means and standard errors, while categorical variables were presented as unweighted counts and weighted proportions. Comparisons between survey cycles were made using the wald-test (categorical variables) or Kruskal-Wallis rank-sum test (skewed distribution).

We used survey-weighted generalized linear regression models to evaluate the trends in BMI, obesity and overweight by survey period. Multivariate survey-weighted generalized linear regression models were adjusted for age, sex, race, education, PIR and activity status. A p-value for trend was obtained by entering the median value of each category of BMI, prevalence of overweight and obesity as a continuous variable in the models, and rerunning the corresponding survey-weighted generalized linear regression models.

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We used a previously described method to compare trends in mean BMI, obesity and overweight before and after 2009-2010 to explore the potential impact on financial crisis around 2008.[25] We calculated mean BMI annual changes as the absolute value of difference in mean BMI between the start and end years divided by total number of years covered. We also calculated the annual relative changes in obesity and overweight prevalence as the absolute value of difference in prevalence between the start and end years divided by the prevalence in the start year annualised by accounting for compounding. Welch's t tests were used to compare trends in mean BMI, obesity and overweight before and after 2009-2010.

All simulations and analyses were performed using R software (R Foundation for Statistical Computing, Vienna, Austria, Version 3.6.3) and the "survey" package (e.g., svymean and svyglm), which considers sampling weights (16-year exam weight), clustering, and stratification of the complex survey design.[26] A two-sided p value <0.05 was considered to be statistically significant.

2.4 Patient and Public Involvement

Approval was obtained from the National Center for Health Statistics Research Ethics Review Board, and all participants provided written informed consent. Therefore there was no need for any ethical consent in this study.

3.Results

The demographic characteristics of all participants according to survey year cycles are listed in Table 1. In total, 42,266 participants (20,408 men and 21,858 women) were included for our final analysis. The mean (SE) age of the weighted population was 47.11 (0.20) years, 47.97% of the population were men, and the weighted mean (SE) BMI was 28.93 (0.07) kg/m^2. Approximately two-thirds (67.36%) were Non-Hispanic White, 11.41% were Non-Hispanic Black, 8.38% were Mexican

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American, 5.33% were Hispanic and 7.51% were other race. More than 80% had a minimum of a high school education. Approximately 80% reported good economic status (PIR ≥ 130%). About 65% reported meeting physical activity guidelines. The prevalence of obesity and overweight increased overtime, whereas the inverse was true for normal weight ($p = 0.002$).

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Table 1. Baseline characteristics of participants.*

Characteristics	National Health and Nutrition Examination Survey cycles †								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Age, years	47.11 ± 0.20	46.02 ± 0.52	46.42 ± 0.74	46.55 ± 0.44	46.92 ± 0.49	47.21 ± 0.82	47.45 ± 0.38	47.92 ± 0.58	48.14 ± 0.53
Age, years (group)									
20 - 30	8,033 (20.5)	940 (21.0)	1,101 (20.5)	928 (20.5)	1,134 (21.1)	1,043 (20.6)	1,025 (20.6)	1,016 (20.2)	846 (19.7)
30 - 39	7,175 (18.4)	759 (20.3)	823 (19.8)	997 (19.1)	1,010 (18.1)	916 (17.5)	951 (17.4)	921 (17.4)	798 (19.0)
40 - 49	7,035 (19.4)	742 (21.6)	782 (21.2)	920 (21.2)	1,063 (19.8)	869 (19.4)	991 (18.9)	896 (17.7)	772 (16.3)
50 - 59	6,714 (18.1)	596 (16.6)	622 (16.9)	902 (17.8)	956 (18.2)	877 (18.9)	914 (18.1)	917 (18.8)	930 (19.3)
60 - 69	6,629 (12.8)	695 (10.2)	631 (11.0)	894 (11.0)	876 (12.0)	820 (13.5)	866 (14.1)	863 (14.5)	984 (15.1)
≥ 70	6,680 (10.8)	915 (10.5)	721 (10.3)	966 (10.5)	955 (10.8)	712 (10.1)	773 (11.0)	793 (11.4)	845 (11.6)
Sex, n (%)									
Male, n (%)	20,408 (48.0)	2,237 (48.1)	2,237 (48.2)	2,746 (48.0)	2,889 (48.1)	2,585 (48.1)	2,638 (48.0)	2,638 (47.6)	2,493 (47.7)
Female, n (%)	21,858 (52.0)	2,410 (51.9)	2,443 (51.8)	2.861 (52.0)	3,105 (51.9)	4,652 (51.9)	2,882 (52.0)	2,882 (52.4)	2,682 (52.3)
Race									
Mexican American	6,805 (8.4)	931 (8.0)	944 (8.0)	967(8.3)	1,096 (8.6)	509 (7.7)	737 (9.1)	936 (8.8)	685 (8.7)
Other Hispanic	3,755 (5.3)	139 (3.5)	148 (3.4)	629 (4.9)	610 (5.0)	538 (6.5)	488 (5.6)	720 (6.4)	483 (6.9)
Non-Hispanic White	18,120 (67.4)	2,464 (72.0)	2,338 (71.9)	2,625 (69.6)	2,865 (67.9)	1,917 (66.5)	2,366 (65.9)	1,767 (64.0)	1,778 (62.4)
Non-Hispanic Black	9,094 (11.4)	910 (11.2)	1,064 (11.4)	1,155 (11.2)	1,087 (11.4)	1,382 (11.5)	1,135 (11.5)	1,142 (11.4)	1,219 (11.5)
Other Race	4,492 (7.5)	203 (5.4)	186 (5.2)	231 (6.1)	336 (7.2)	891 (7.7)	794 (7.9)	841 (9.4)	1,010 (10.5)
Education, n (%)									
Less than high school	10,814 (16.4)	1,362 (18.1)	1,290 (17.4)	1,728 (20.3)	1,710 (18.9)	1,235 (16.4)	1,191 (15.2)	1,277 (14.3)	1,021 (11.0)
High school graduate	9,787 (23.6)	1,167 (27.1)	1,119 (25.0)	1,392 (25.4)	1,376 (22.9)	1,098 (19.8)	1,232 (21.6)	1,172 (20.8)	1,231 (27.0)

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Some college or AA degree	12,266 (31.4)	1,263 (31.5)	1,334 (31.3)	1,440 (29.0)	1,679 (30.3)	1,576 (32.4)	1,704 (32.9)	1,602 (32.5)	1,668 (30.8)
College graduate or above	9,345 (28.6)	847 (23.2)	931 (26.1)	1,041 (25.3)	1,216 (27.7)	1,324 (31.3)	1,389 (30.3)	1,352 (32.4)	1,245 (31.1)
Poverty income ratio, n (%)									
< 130%	12,129 (21.3)	1,264 (20.5)	1,167 (17.1)	1,552 (20.4)	1,817 (21.7)	1,724 (24.6)	1,762 (24.7)	1,568 (20.9)	1,275 (20.1)
≥ 130%	26,450 (78.7)	3,119 (79.5)	3,294 (82.9)	3,536 (79.6)	3,592 (78.3)	3,078 (75.4)	3,335 (75.3)	3,280 (79.1)	3,216 (79.9)
BMI, kg/m^2	28.93 ± 0.07	28.24 ± 0.15	28.57 ± 0.23	28.54 ± 0.16	28.75 ± 0.13	28.73 ± 0.21	29.17 ± 0.17	29.42 ± 0.25	29.86 ± 0.26
BMI, kg/m^2 (group)									
< 25	12,522 (30.7)	1,480 (33.7)	1,432 (32.9)	1,628 (32.0)	1,684 (30.9)	1,714 (31.7)	1,700 (30.0)	1,517 (28.7)	1,367 (26.9)
25 - 30	14,046 (32.9)	1,632 (34.1)	1,608 (32.9)	1,934 (34.3)	2,030 (33.4)	1,677 (33.8)	1,767 (32.6)	1,731 (31.9)	1,667 (30.8)
≥ 30	15,698 (36.4)	1,535 (32.2)	1,640 (34.2)	2,045 (33.7)	2,280 (35.8)	1,846 (34.6)	2,053 (37.4)	2,158 (39.4)	2,141 (42.3)
Total energy intake, Kcal/d	2,027.31±7.96	2,113.90 ± 13.81	2,051.01 ± 25.07	2016.62 ± 20.87	2061.43±27.10	2014.61 ± 18.59	2017.22 ± 23.24	1970.20 ± 23.28	1980.34 ± 23.18
Physical activity, n (%)									
Inactive	8,504 (18.1)	150 (5.6)	142 (4.4)	1,656 (23.1)	1,711 (23.7)	355 (6.8)	1,562 (26.3)	1,565 (23.0)	1,363 (21.2)
Insufficiently active	6,649 (17.5)	1,380 (50.2)	1,403 (47.5)	734 (13.0)	817 (13.7)	536 (10.3)	568 (9.7)	567 (9.9)	644 (11.3)
Sufficiently active	23,320 (64.4)	1,156 (44.2)	1,303 (48.2)	3,217 (63.8)	3,466 (62.7)	4,346 (82.9)	3,390 (64.0)	3,274 (67.1)	3,168 (67.5)

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003-2018).

† Values are presented as mean ± SE for continuous variables and unweighted numbers (weighted %) for categorical variables.

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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The mean(SE) BMI levels rose from 28.24 (0.07) kg/m^2 in 2003-2004 to 29.86(0.26) kg/m^2 in 2017-2018 (Table S1). In 2017-2018, the obesity prevalence was 42.8% (95% CI 39.5-46.1), increasing more than 10% compared with 2003-2004 (32.3%, 95% CI 29.9-34.6) (Table S2). Consistent with the increase in mean BMI and obesity prevalence, we found that the prevalence of overweight rose from 66.3% (95% CI 64.4-68.3) in 2003-2004 to 73.8 (95% CI 71.1-76.4) in 2017-2018 (Table S3). We used survey-weighted generalized linear regression models to evaluate the trends in BMI, obesity and overweight by survey period (Table 2). Compared with 2003-2004, the mean (SE) BMI increased by 1.96 kg/m^2 (95% CI 1.34-2.57, $p < .001$) in 2017-2018 after adjusting for age, sex, race, education, PIR and activity status (Table 2, Table S4). The findings were similar for the prevalence of obesity and overweight. Compared with 2003-2004, the adjusted odd ratios for the prevalence of obesity and overweight were 1.15 (95% CI 1.10-1.21, $p < .001$) and 1.08 (95% CI 1.04-1.13, $p < .001$), respectively (Table 2, Table S5, Table S6). However, we found no significant effect of survey cycle on the prevalence of overweight among men after adjusting for potential confounding variables (adjusted odd ratio 1.05, 95%CI 1.00-1.11, $p = 0.050$) (Table S6).

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Table 2. Change in BMI, obesity and overweight overtime among adults in the United States, 2003-2018

Years	Mean BMI		Prevalence of obesity		Prevalence of overweight	
	Adjusted β * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	0.38 (-0.23,0.99)	0.215	1.03 (0.99, 1.07)	0.184	1.01 (0.97, 1.05)	0.598
2007 - 2008	0.48 (0.04,0.93)	0.035	1.03 (1.00, 1.06)	0.084	1.02 (0.98, 1.05)	0.281
2009 - 2010	0.70 (0.26,1.15)	0.002	1.06 (1.03, 1.09)	<0.001	1.03 (0.99, 1.07)	0.178
2011 - 2012	1.08 (0.55, 1.61)	<0.001	1.07 (1.03, 1.11)	<0.001	1.05 (1.00, 1.09)	0.034
2013 - 2014	1.18 (0.66, 1.70)	<0.001	1.08 (1.04, 1.11)	<0.001	1.05 (1.01, 1.08)	0.012
2015 - 2016	1.59 (1.03, 2.20)	<0.001	1.11 (1.07, 1.16)	<0.001	1.06 (1.02,1.10)	0.005
2017 - 2018	1.96 (1.34, 2.57)	<0.001	1.15 (1.10, 1.21)	<0.001	1.08 (1.04, 1.13)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio.

* Models adjusted for age, sex , race, education, family poverty income ratio, total energy intake and physical activity status.

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Table 3 shows the annual change in mean BMI as well as obesity and overweight prevalence during 2003-2004 to 2009-2010 and 2011-2012 to 2017-2018. The increase of mean BMI was somewhat bigger after 2009-2010 (0.12 kg/m^2 annual relative increase, 95% CI 0.06-0.19) compared with before 2009-2010 (0.07 kg/m^2 annual relative increase, 95% CI 0.02-0.13). But, this difference was not statistically significant (p = 0.848). Annual changes in prevalence of obesity and overweight were similar. The acceleration in the rise of obesity prevalence was mainly due to an increase in the prevalence of obesity among those who are in a better economic position (0.40% annual relative increase, 95% CI -1.11-1.93 vs 2.97% annual relative increase, 95% CI 1.75-4.20). Again, this difference was not statistically different (p=0.985). Likewise, for the prevalence of overweight, the annual increase was also numerically faster after 2009-2010 compared with before 2009-2010 (0.6%, 95% CI -0.08-1.27 vs 0.72%, 0.15-1.29; p = 0·584). Remarkably, the prevalence of overweight was nearly unchanged among those with poor economic conditions after 2009-2010 (0.00 annual relative increase, 95% CI -0.96-0.97) compared with before 2009-2010 (1.82 annual relative increase, 95% CI 0.55-3.10, p = 0.037). Meanwhile, both men and women with poor economic conditions slowed down the increase of BMI and the prevalence of obesity and overweight after 2009-2010 compared with before 2009-2010. In contrast, a bigger increase was found among those with good economic conditions after 2009-2010, although without statistical significance(p > 0.05).

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Table3. Annual change in BMI, obesity and overweight during 2003-2010 and 2011–2018

Characteristic	Men			Women			Both		
	2003/04-2009/2010	2011/12-2017/2018	p-value*	2003/2004-2009/2010	2011/2012-2017/2018	p-value*	2003/2004-2009/2010	2011/2012-2017/2018	p-value*
Change (95% CI) in mean BMI (kg/m²)									
Overall	0.07 (0.02, 0.13)	0.12 (0.06, 0.19)	0.848	0.65 (-0.01, 0.14)	0.13 (-0.39, 2.76)	0.846	0.07 (0.02, 0.13)	0.12 (0.06, 0.19)	0.848
PIR<130%	0.17 (0.02, 0.32)	0.08 (-0.06, 0.22)	0.245	0.17 (0.04, 0.30)	0.06 (-0.09, 0.21)	0.186	0.17 (0.05, 0.28)	0.07 (-0.04, 0.18)	0.170
PIR⩾130%	0.07 (-0.01, 0.14)	0.11 (0.04, 0.17)	0.716	0.15 (-0.04, 0.13)	0.16 (0.07, 0.25)	0.943	0.06 (0.00, 0.11)	0.13 (0.07, 0.20)	0.922
Percentage change (95% CI) in obesity prevalence									
Overall	1.93 (0.10, 3.76)	2.29 (0.54, 4.02)	0.589	1.15 (-0.39, 2.76)	1.71 (0.56, 2.84)	0.699	1.51 (0.24, 2.81)	1.99 (0.93, 3.04)	0.689
PIR<130%	3.16 (0.12, 6.19)	2.38 (-0.48, 5.25)	0.378	2.38 (0.34, 4.46)	0.95 (-0.77, 2.67)	0.192	2.56 (0.81, 4.31)	1.47 (0.00, 2.95)	0.223
PIR⩾130%	1.93 (-0.03, 3.85)	2.08 (-0.38, 3.77)	0.536	0.97 (-1.00, 3.00)	2.21 (0.62, 3.78)	0.796	0.40 (-1.11, 1.93)	2.97 (1.75, 4.20)	0.985
Percentage change (95% CI) in overweight prevalence									
Overall	0.69 (-0.18, 1.56)	0.50 (-0.24, 1.24)	0.393	0.50 (-0.45, 1.47)	0.95 (0.30, 1.60)	0.746	0.60 (-0.08, 1.27)	0.72 (0.15, 1.29)	0.584
PIR<130%	2.64 (-0.52, 4.82)	-0.06 (-1.60, 1.50)	0.050	1.33 (0.10, 2.56)	0.03 (-0.97, 1.04)	0.096	1.82 (0.55, 3.10)	0.00 (-0.96, 0.97)	**0.037**
PIR⩾130%	0.36 (-0.59, 1.31)	0.64 (-0.03, 1.33)	0.646	0.28 (-0.81, 1.40)	1.31 (0.55, 2.08)	0.900	0.30 (-0.50, 1.10)	0.95 (0.34, 1.56)	0.844

Abbreviations: BMI, body mass index; CI, confidence interval; PIR poverty income ratio.

* p-value for difference in annual changes for 2004-2010 versus 2011-2018.

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Graphical representations of the changes in the distribution of mean BMI, obesity and overweight prevalence are shown in the Figure1 and Figure2. Similar trends in mean BMI were found across subgroups of age, PIR, education, race, sex and activity status. Overall, the mean BMI generally increased overtime among all participants. In age subgroup, the lowest mean BMI was found in those aged 20–30 years, followed by those aged > 70 years(Table S1, Figure1). Compared to good economic conditions, BMI was higher for those with poor economic conditions since 2005-2006. In 2017-2018, participants with poor economic conditions had a mean BMI 1.68 kg/m^2 lower than those with good economic conditions. Between 2003-2004 and 2017-2018, lower mean BMI was found among participants with a higher educational level than among those with a lower educational level. A similar trend was found in the subgroup stratified by race. In 2017-2018, mean (SE) BMI for all participants was 29.86 ± 0.26 kg/m^2, with the highest mean BMI in Non-Hispanic Blacks (31.29 ± 0.29) and the lowest BMI in other race population (28.21 ± 0.39) (Table1, Figure1). From 2003-2004 to 2017-2018, the mean BMI rose similarly in both sexes, by about 1.61 kg/m^2 totally for men and 1.64 kg/m^2 for women (Table S1, Figure2). Meanwhile, men had a lower BMI than women. In activity status subgroup, there was a more complex pattern, with a decrease in mean BMI in 2011-2012 among those who were inactive and insufficiently active. Although there was an acceleration in the rise of mean BMI among those who were sufficiently active, their mean BMI was the lowest.

The trends in increasing obesity prevalence overtime were largely consistent for men and women. In 2003-2004, men had lower mean BMI and lower prevalence of obesity than women, but a reversed pattern was seen in 2017-2018. In 2017-2018, men had a higher prevalence of obesity than women (43.3%, 95% CI 38.2-48.4 vs 42.3%, 38.6-46.0) (Table S2, Figure2).

The trends in increasing overweight prevalence overtime were similar for both sexes. Overall,

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overweight prevalence in men was higher than in women. Between 2003-2004 and 2017-2018, the overweight rose similarly in both sexes, by about 1.61 kg/m^2 totally for men and 1.64 kg/m^2 for women. As for overweight prevalence trends, there was increasing prevalence of men from 70.6% (95%CI 68.0-73.0) in 2003-20044 to 77.4% (95%CI 73.9-80.9) in 2017-2018, and of women from 62.5% (95%CI 59.9-65.9) to 70.5% (95%CI 67.3-73.6) (Table S3, Figure2).

4.Discussion

Based on this nationally representative sample of United States population from 20013-2014 though 2017-2018, the present study showed that, the prevalence of obesity among American adults increased from 32.3% in 2003-2004 to 42.8% in 2017-2018. For the years 2017-2018, the prevalence of obesity was 42.3% among men and 43.3% among women. Compared with 2003-2004, the mean BMI increased by 1.94 kg/m^2, by 15% for obesity prevalence and by 8% for overweight prevalence in 2017-2018 after adjusting for age, sex, race, education, PIR and activity status. The rises in mean BMI and the prevalence of both obesity and overweight were somewhat bigger after 2009-2010 compared with before 2009-2010. However, the difference was not statistically significant.

The levels and changes in trends of mean BMI and obesity prevalence among American adults have been covered by numerous studies.[9 15 27-29] The National Center for Health Statistics (NCHS) reported that the age-adjusted obesity prevalence among adults was 42.4% in 2017-2018, and obesity prevalence increased among adults From 1999-2000 through 2017-2018.[15] Another study using data from the 2005–2014 NHANES also showed that a statistically significant positive linear trend in obesity prevalence were present in women but not in men.[28] One recent study suggested that the prevalence of obesity among US adults rose from 35.4% in 2011-2012 to 43.4% in 2017-2018. From 2011-2012 through 2017-2018, mean BMI rose from 28.7 kg/m^2 to 29.8 kg/m^2.[29] Our results were

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broadly consistent with the results of the above studies at each timepoints. However, our present study used a larger sample size as well as a longer time span.

To the best of our knowledge, few studies have assessed annual change in BMI and obesity, and the potential effects of financial crisis around 2009 among US adults. A previous study conducted using NHANES data 1999–2008 showed that the increases in the prevalence of obesity do not appear to be continuing at the same rate from 1999-2000 through 2007-2008. When they adjusted for age and race group with survey period as a categorical variable, there were no significant differences in prevalence of obesity between 2003-2004 and 2007-2008 for men.[27] This is broadly consistent with our findings. In our study, statistically significant differences in mean BMI and obesity prevalence for both sexes were found since 2009-2010 (Table 2). Furthermore, a previous study evaluated the effects of economic crisis on dietary quality and obesity rates.[30] They found that economic changes can modify diet quality increase the risk to have a poor diet or to be obese, which was mainly due to the changes in economic and work conditions. In our present study, although the differences were not statistically significant, numerical larger increases in mean BMI and the prevalence of both obesity and overweight were found after 2009-2010 compared with before 2009-2010.

In addition，although the mean BMI and the prevalence of obesity and overweight increased overtime, the mean daily intake of energy decreased from 2003-2004 to 2017-2018 (2,113.90±7.96 Kcal/d vs 1,980.34±7.96 Kcal/d, $p < 0.001$). Several mechanisms may explain this phenomenon: (1) The reduction in energy intake may led to hunger increases and energy expenditure declines-physiological adaptations that tend to push body weight back up.[31] (2) In the US, carbohydrate intake has increased markedly, resulting in major increases in the proportion of calories from carbohydrates.[32] A high-carbohydrate diet could produce postprandial hyperinsulinemia, which promotes energy storage

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and causes an increase in body weight.[33]

In our study, lower mean BMI was found among participants with a higher educational level than among those with a lower educational level. A previous study showed that higher educational level is related to lower BMI level among mid-age women, mainly on account of selection.[34] It is also reported that young overweight/obese women were more likely to have a lower educational level.[34] It might be explained by the following reasons: (1) Children with a lower BMI tend come from socioeconomically advantaged families, and have better chances of completing their studies.[34] (2) Children with a lower BMI may benefit from physical activity, which may have a positive influence on academic performance.[35] (3) Negative views on high-BMI children may impair their academic performance.[36]

Although NHANES is designed to provide nationally representative estimates, it is a repeated cross sectional, which precludes within-individual change in BMI or obesity. Meanwhile, obesity was defined mainly based on measurements of BMI, which does not measure body fat directly. Although BMI is highly correlated with overall body fat[37], the relationship between BMI and body fat varies by sex, age, and race-ethnicity[38]. In addition, the use of a large nationally representative sample of adults from the United States. Thus, our results are only generalizable to the US population. Therefore, there are certain limitations in the extrapolation of the study results.

The COVID-19 global pandemic has changed the lifestyle of most Americans. It has been reported that approaches designed to contain the spread of COVID-19 such as lockdowns might exacerbate the prevalence of obesity.[39] The effects of the COVID-19 global pandemic on BMI and prevalence of obesity are not fully understood. Regrettably, information about anthropometric measurements in NHANES after 2018 has not been released. Additional follow-up studies are required to answer these questions.

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5.Conclusions

Although the prevalence of adult obesity continues to rise, there have been no significant changes in rising rate of adult obesity prevalence between 2003-2004 and 2017-2018. In 2017-2018,the prevalence of obesity was 43.3% among adult men and 42.3% among adult women.

Author contributions:

WG, ZL: designed the research; ZL and ML: analyzed the data; ZL: wrote the paper; ZL: had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis; WG, ZL,ML and SW: assisted with interpretation of the results and critically reviewed the manuscript; and all authors: read and approved the final manuscript. The authors report no conflicts of interest.

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Competing interests statement

None.

Data sharing statement

Data described in the article are publicly and freely available without restriction at https://www.cdc.gov/nchs/nhanes/index.htm.

Ethics approval

Approval was obtained from the National Center for Health Statistics Research Ethics Review

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Board, and all participants provided written informed consent (Approval number: Protocol#98-12, #2005-06, #11-17, #18-01, https://www.cdc.gov/nchs/nhanes/irba98.htm).

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Figure legends

Figure1 Mean BMI by age (A), poverty income ratio (B), education (C) and race (D) group from 2003 to 2018.

Figure2 Mean BMI by sex (A), activity status (B)group and prevalence of overweight (C) and obesity (D) from 2003 to 2018.

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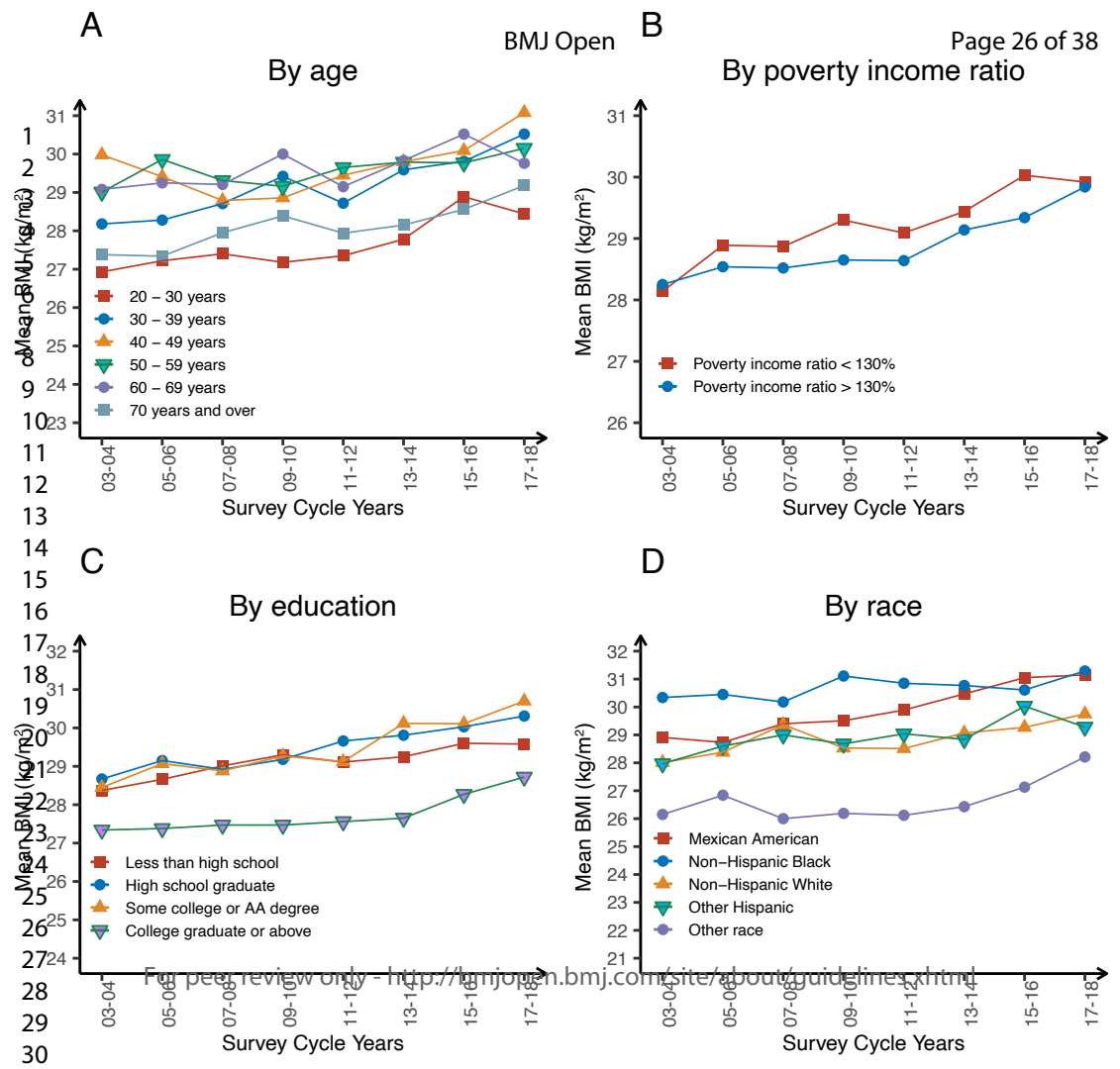

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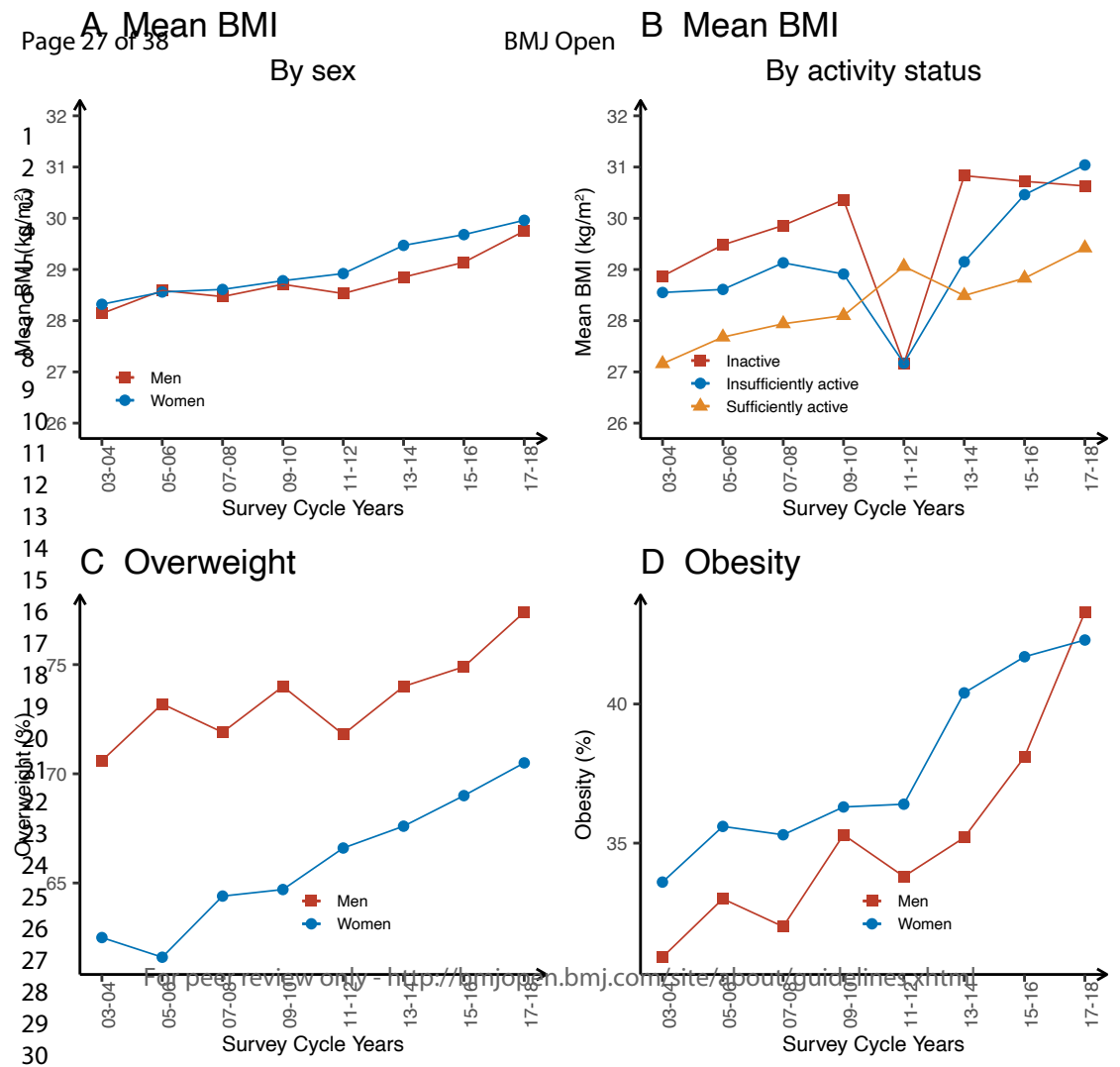

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For the annual change in mean BMI and annual relative change in prevalence of obesity and overweight, the calculation formulas were as follows:

- Annual change in mean BMI (kg/m^2):

$$\text{annual change} = \frac{(\text{level}_{t2} - \text{level}_{t1})}{(t2 - t1)}$$

- Annual relative change in prevalence of obesity and overweight:

$$\text{annual change} = \left(\frac{\text{level}_{t2}}{\text{level}_{t1}}\right)^{\frac{1}{t2-t1}} - 1$$

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eTable 1. Mean BMI overtime among adults in the United States, 2003-2018 [a]

Characteristics	BMI (weighted mean ± SE), kg/m^2								
	Total (n= 42,266)	2003/2004 (n = 4,647)	2005/2006 (n = 4,680)	2007/2008 (n = 5,607)	2009/2010 (n = 5,994)	2011/2012 (n = 5,237)	2013/2014 (n = 5,520)	2015/2016 (n = 5,406)	2017/2018 (n = 5,175)
Overall	28.93 ± 0.07	28.24 ± 0.15	28.57 ± 0.23	28.54 ± 0.16	28.75 ± 0.13	28.73 ± 0.21	29.17 ± 0.17	29.42 ± 0.25	29.86 ± 0.26
Age, years									
20 - 30	27.54 ± 0.14	26.93 ± 0.21	27.22 ± 0.34	27.40 ± 0.45	27.18 ± 0.30	27.35 ± 0.38	27.78 ± 0.42	28.89 ± 0.39	28.44 ± 0.55
30 - 39	29.16 ± 0.13	28.18 ± 0.37	28.28 ± 0.36	28.71 ± 0.28	29.42 ± 0.32	28.72 ± 0.33	29.59 ± 0.35	29.81 ± 0.31	30.52 ± 0.48
40 - 49	29.53 ± 0.13	28.98 ± 0.28	29.41 ± 0.32	28.79 ± 0.27	28.86 ± 0.22	29.45 ± 0.35	29.80 ± 0.42	30.09 ± 0.52	31.08 ± 0.36
50 - 59	29.61 ± 0.14	29.01 ± 0.41	29.86 ± 0.43	29.31 ± 0.42	29.16 ± 0.24	29.65 ± 0.51	29.79 ± 0.31	29.77 ± 0.40	30.15 ± 0.32
60 - 69	29.66 ± 0.13	29.08 ± 0.23	29.25 ± 0.29	29.21 ± 0.33	30.00 ± 0.29	29.15 ± 0.40	29.83 ± 0.32	30.52 ± 0.40	29.76 ± 0.46
≥ 70	28.16 ± 0.10	27.38 ± 0.23	27.34 ± 0.25	27.95 ± 0.25	28.39 ± 0.22	27.94 ± 0.31	28.15 ± 0.24	28.56 ± 0.35	29.18 ± 0.26
Sex									
Male	28.79 ± 0.08	28.14 ± 0.13	28.59 ± 0.25	28.47 ± 0.16	28.71 ± 0.21	28.53 ± 0.23	28.85 ± 0.15	29.14 ± 0.26	29.75 ± 0.27
Female	29.07 ± 0.09	28.32 ± 0.24	28.56 ± 0.28	28.61 ± 0.20	28.78 ± 0.14	28.92 ± 0.23	29.47 ± 0.26	29.68 ± 0.29	29.96 ± 0.37
Race									
Mexican American	29.96 ± 0.13	28.91 ± 0.39	28.73 ± 0.22	29.40 ± 0.31	29.51 ± 0.27	29.89 ± 0.38	30.47 ± 0.24	31.05 ± 0.33	31.15 ± 0.35
Other Hispanic	29.05 ± 0.15	27.97 ± 0.64	28.60 ± 0.51	29.00 ± 0.41	28.68 ± 0.41	29.04 ± 0.31	28.84 ± 0.50	30.03 ± 0.40	29.28 ± 0.33
Non-Hispanic White	28.73 ± 0.09	28.01 ± 0.18	28.38 ± 0.25	28.37 ± 0.26	28.53 ± 0.16	28.51 ± 0.28	29.07 ± 0.19	29.27 ± 0.26	29.75 ± 0.35
Non-Hispanic Black	30.72 ± 0.11	30.34 ± 0.31	30.45 ± 0.28	30.18 ± 0.30	31.11 ± 0.35	30.85 ± 0.28	30.77± 0.31	30.61± 0.34	31.29 ± 0.29
Other race	26.77 ± 0.16	26.15 ± 0.52	26.84 ± 0.65	26.00 ± 0.55	26.19 ± 0.39	26.12 ± 0.41	26.43 ± 0.36	27.13 ± 0.42	28.21 ± 0.39
Education									
Less than high school	29.09 ± 0.09	28.37 ± 0.32	28.66 ± 0.16	29.01 ± 0.25	29.30 ± 0.22	29.11 ± 0.28	29.25 ± 0.21	29.60 ± 0.29	29.58 ± 0.37
High school graduate	29.47 ± 0.10	28.67 ± 0.20	29.15 ± 0.27	28.92 ± 0.29	29.18 ± 0.20	29.66 ± 0.37	29.81 ± 0.33	30.03 ± 0.38	30.31 ± 0.18

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Some college or AA degree	29.51 ± 0.10	28.45 ± 0.22	29.07± 0.29	28.88 ± 0.25	29.27 ± 0.17	29.12 ± 0.28	30.12 ± 0.27	30.11 ± 0.33	30.70 ± 0.32
College graduate or above	27.78 ± 0.11	27.34 ± 0.33	27.38 ± 0.37	27.40 ± 0.28	27.47 ± 0.30	27.56 ± 0.34	27.65 ± 0.20	28.27 ± 0.26	28.72 ± 0.43
Poverty income ratio									
< 130%	28.14 ± 0.22	28.14 ± 0.22	28.89 ± 0.31	28.87 ± 0.28	29.30± 0.34	29.09± 0.21	29.44± 0.21	30.03 ± 0.32	29.92 ± 0.39
≥ 130%	28.25 ± 0.15	28.25 ± 0.15	28.54 ± 0.24	28.52 ± 0.16	28.65 ± 0.15	28.64 ± 0.26	29.14 ± 0.23	29.34 ± 0.27	28.24 ± 0.15
Physical activity									
Inactive	28.53 ± 0.09	28.87 ± 0.72	29.48 ± 0.82	29.86 ± 0.21	30.36 ± 0.21	27.16 ± 0.35	30.83 ± 0.30	30.72± 0.33	30.63 ± 0.39
Insufficiently active	28.98 ± 0.12	28.55 ± 0.20	28.61 ± 0.28	29.13 ± 0.34	28.91 ± 0.21	27.17 ± 0.38	29.15 ± 0.32	30.46 ± 0.58	31.04 ± 0.42
Sufficiently active	28.53 ± 0.09	27.16 ± 0.23	27.68 ± 0.27	27.94 ± 0.20	28.10± 0.18	29.06 ± 0.22	28.49 ± 0.17	28.83 ± 0.25	29.42 ± 0.29

[a] Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003–2018).

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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eTable 2. Prevalence of obesity overtime among adults in the United States, 2003-2018 [a]

Characteristics	Prevalence (95CI),%								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Overall	36.7 (35.7, 37.6)	32.3 (29.9, 34.6)	34.4 (31.6, 37.2)	33.7 (31.5, 35.9)	35.8 (34.0, 37.7)	35.2 (32.4, 37.9)	37.9 (36.2, 39.6)	40.0 (37.0, 43.0)	42.8 (39.5, 46.1)
Age, years									
< 30	29.6 (27.9, 31.4)	26.1 (23.1, 29.0)	27.7 (22.7, 32.6)	27.4 (21.6, 33.2)	27.7 (24.0, 31.4)	29.0 (23.9, 34.1)	29.5 (25.8, 33.1)	31.7 (26.7, 36.7)	37.5 (30.2, 44.8)
30 - 39	37.1 (35.5 ,38.7)	32.5 (27.6, 37.5)	31.1 (26.6, 35.6)	35.5 (30.5, 39.7)	39.7 (35.4, 44.1)	33.5 (30.2, 36.9)	39.9 (35.9, 43.9)	40.5 (37.0, 44.1)	44.3 (38.8, 49.9)
40 - 49	39.3 (37.7, 40.9)	36.7 (34.2, 39.2)	39.0 (34.4, 43.6)	33.7 (29.4, 38.1)	36.2 (33.0, 39.5)	38.8 (33.4, 44.2)	41.1 (35.7, 46.5)	44.0 (38.1, 49.8)	46.3 (41.7, 51.0)
50 - 59	40.5 (38.6, 42.4)	35.9 (29.6, 42.1)	43.2 (38.6, 47.7)	38.1 (32.5, 43.6)	37.2 (33.8, 40.5)	39.5 (33.2, 45.9)	41.7 (37.1, 46.3)	42.7 (35.8, 49.6)	44.9 (40.7, 49.1)
60 - 69	41.6 (39.6, 43.6)	35.7 (32.1, 39.3)	38.7 (34.1, 43.3)	38.6 (34.4, 42.8)	43.8 (39.7, 48.0)	39.5 (34.5, 44.6)	42.9 (38.9, 46.9)	46.0 (40.3, 51.6)	43.3 (35.3 ,51.4)
≥ 70	32.2 (30.7, 33.6)	26.2 (22.4, 30.0)	25.8 (21.4, 30.2)	30.9 (27.0, 34.8)	33.4 (30.0, 36.8)	29.5 (26.4, 32.7)	32.7 (28.4 ,37.0)	35.5 (30.9, 40.1)	40.3 (36.0, 44.6)
Sex									
Men	35.3 (34.1, 36.6)	30.9 (28.4 ,33.4)	33.0 (28.9, 37.1)	32.0 (29.1, 34.8)	35.3 (31.9, 38.7)	33.8 (31.2, 36.4)	35.2 (33.2, 37.2)	38.1 (33.9, 42.3)	43.3 (38.2, 48.4)
Women	37.9 (36.8, 38.9)	33.6 (30.3, 36.8)	35.6 (33.0, 38.3)	35.3 (33.0, 37.6)	36.3 (34.5, 38.1)	36.4 (33.0, 39.8)	40.4, 37.9, 43.0)	41.7 (38.7, 44.7)	42.3 (38.6, 46.0)
Race									
Mexican American	43.1 (41.5, 44.8)	36.3 (31.2, 41.4)	33.3 (31.6, 35.1)	39.2 (32.2, 46.2)	38.9 (36.4, 43.4)	45.2 (40.7, 49.7)	46.7 (42.5, 51.0)	49.0 (45.6, 52.4)	51.6 (47.5, 55.8)
Other Hispanic	37.0 (35.0, 39.1)	29.5 (19.2, 39.8)	34.2 (26.6, 41.9)	34.9 (30.3, 39.6)	34.7 (28.8, 40.6)	38.1 (32.7, 43.6)	36.9 (31.2, 42.6)	44.2 (38.4, 49.9)	37.0 (42.7, 41.2)
Non-Hispanic White	35.5 (34.4, 36.6)	31.0 (28.5, 33.4)	33.3 (30.2, 36.5)	32.6 (29.2, 36.0)	34.7 (32.4, 37.1)	33.4 (29.9, 37.0)	37.0 (35.0, 39.1)	38.9 (35.7, 42.1)	43.0 (38.2, 47.7)
Non-Hispanic Black	47.1 (45.7, 48.5)	45.2 (40.9, 49.4)	45.4 (42.0, 48.8)	43.6 (39.6, 47.5)	49.9 (45.1, 54.7)	47.8 (44.3, 51.2)	47.9 (43.8, 52.1)	46.8 (42.5, 51.1)	49.8 (46.9, 52.7)
Other race	23.7 (21.4, 25.9)	19.0 (9.9, 28.0)	26.4 (17.6, 35.2)	19.4 (9.9, 29.0)	19.7 (15.4, 24.0)	18.8 (13.9, 23.8)	21.4 (16.7, 26.0)	28.0 (21.3, 36.7)	30.6 (25.5, 35.7)
Education									
Less than high school	37.9 (36.7, 39.2)	34.3 (30.0, 38.5)	35.7 (33.3, 38.1)	37.6 (33.1, 42.0)	37.6 (34.9, 40.3)	37.7 (35.1, 40.4)	40.6 (37.5, 43.6)	40.3 (36.3, 43.7)	41.4 (37.3, 45.6)
High school graduate	40.0 (38.5, 41.4)	34.3 (30.5, 38.1)	38.9 (35.1, 42.6)	35.0 (31.6, 38.4)	38.3 (34.6, 42.0)	40.3 (35.3, 45.5)	41.3 (37.0, 45.7)	43.7 (38.6, 48.9)	47.2 (43.2, 51.2)
Some college or AA	40.7 (39.4, 41.9)	33.9 (30.4, 37.4)	36.8 (32.9, 40.7)	37.5 (34.4, 40.6)	40.6 (38.3, 42.9)	38.0 (34.0, 41.9)	42.9 (40.1, 45.7)	46.0 (42.2, 49.8)	47.7 (43.8, 51.5)

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degree									
College graduate or above	28.8 (27.2, 30.4)	26.3 (22.0, 30.7)	26.2 (21.9, 30.5)	24.9 (20.9, 28.9)	27.5 (23.7, 31.4)	27.6 (22.5, 32.8)	28.7 (26.2, 31.3)	31.5 (27.5, 35.4)	34.7 (29.1, 40.2)
Poverty income ratio									
< 130%	38.4 (37.2, 39.6)	32.3 (29.7, 34.6)	36.3 (33.1, 39.6)	35.9 (32.1, 39.7)	38.4 (34.8, 41.9)	38.0 (35.5, 40.6)	39.4 (36.9, 41.8)	42.0 (38.1, 45.9)	43.8 (39.7, 47.9)
≥ 130%	36.4 (35.3, 37.4)	32.3 (29.6, 34.9)	34.3 (31.0, 37.6)	33.1 (30.9, 35.4)	35.7 (33.4, 37.9)	34.3 (31.0, 37.6)	37.6 (35.3, 40.0)	39.8 (36.3, 43.2)	43.1 (39.6, 46.7)
Physical activity									
Inactive	44.8 (43.4, 46.2)	38.0 (30.4, 45.6)	41.7 (29.5, 53.9)	42.6 (39.7, 45.4)	44.4 (42.4, 46,4)	26.2 (20.0, 32.3)	48.5 (44.9, 52.1)	48.0 (44.5, 51.5)	46.7 (43.1, 50.4)
Insufficiently active	36.4 (34.8, 38.0)	33.7 (30.6, 36.7)	34.0 (30.8, 37.3)	36.3 (31.1, 41.4)	37.3 (33.0, 41.6)	27.4 (22.0, 32.8)	36.9 (33.6, 40.1)	44.5 (37.2, 51.8)	48.3 (41.7, 54.9)
Sufficiently active	34.3 (33.2,35.4)	24.8 (21.5, 28.2)	29.1 (24.9, 33.4)	30.0 (27.5, 32.5)	32.3 (29.7, 34.9)	36.9 (34.2, 39.5)	33.7 (31.9, 35.5)	36.6 (33.4, 39.7)	40.6 (36.7, 44.6)

[a] Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003–2018).

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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eTable 3. Prevalence of overweight overtime among adults in the United States, 2003-2018 [a]

Characteristics	Prevalence (95CI),%								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Overall	69.6 (68.7, 70.5)	66.3 (64.4, 68.3)	67.2 (64.6, 69.8)	68.0 (66.2, 69.8)	69.2 (66.6, 71.7)	69.1 (65.9, 72.3)	70.7 (69.0, 72.3)	71.8 (68.9, 74.8)	73.8 (71.1, 76.4)
Age, years									
20 - 30	56.6 (54.7, 58.5)	53.4 (49.1, 57.6)	56.4 (51.9, 60.8)	55.2 (51.1, 59.3)	56.7 (50.7, 62.7)	54.9 (47.4, 62.3)	56.6 (52.4, 60.9)	59.7 (55.3, 64.1)	59.4 (53.2, 65.5)
30 - 39	69.8 (68.1, 71.4)	63.0 (57.7, 68.4)	64.6 (59.1, 70.0)	69.3 (65.9, 72.8)	70.7 (67.0, 74.5)	68.6 (64.4, 72.7)	72.3 (68.2, 76.3)	73.2 (69.5, 76.8)	76.2 (70.6, 81.8)
40 - 49	74.0 (72.4, 75.5)	73.9 (69.2, 78.6)	70.2 (66.2, 74.2)	71.4 (67.6, 75.3)	69.6 (66.4, 72.9)	75.9 (71.7, 80.1)	76.6 (73.0, 80.2)	73.9 (68.7, 79.0)	80.9 (75.5, 86.3)
50 - 59	74.0 (72.4, 75.6)	71.1 (66.7, 75.5)	75.5 (91.0, 79.9)	71.9 (66.7, 77.1)	74.3 (70.0, 78.5)	75.2 (70.6, 79.8)	74.6 (72.2, 77.0)	74.1 (69.6, 78.7)	74.8 (69.3, 80.4)
60 - 69	77.1 (75.4, 78.8)	76.7 (73.4, 80.1)	76.7 (71.7, 81.6)	75.5 (71.4, 79.6)	78.6 (74.7, 82.5)	74.4 (68.3, 80.6)	76.0 (72.5, 79.5)	80.1 (74.5, 85.7)	78.1 (73.6, 82.5)
≥ 70	70.2 (68.9, 71.4)	65.6 (61.0, 70.2)	63.9 (60.4, 67.4)	69.1 (65.8, 72.4)	71.0 (68.2, 73.8)	67.4 (63.8, 70.9)	70.8 (68.2, 73.4)	73.8 (70.2, 77.4)	77.1 (73.5, 80.7)
Sex									
Male	73.5 (72.5, 75.6)	70.6 (68.0, 73.0)	73.2 (70.3, 76.2)	71.9 (70.1, 73.7)	74.0 (70.4, 77.6)	71.8 (68.6, 75.0)	74.0 (71.9, 76.1)	74.9 (72.0, 77.8)	77.4 (73.9, 80.9)
Female	66.0 (64.9, 67.1)	62.5 (59.9, 65.9)	61.6 (58.3, 64.8)	64.4 (61.7, 67.1)	64.7 (62.3, 67.1)	66.6 (63.0, 70.2)	67.6 (65.2, 70.0)	69.0 (65.4, 72.6)	70.5 (67.3, 73.6)
Race									
Mexican American	79.7 (78.1, 81.2)	73.8 (67.8, 79.8)	73.4 (69.8, 77.0)	77.3 (73.3, 81.2)	79.9 (76.5, 83.3)	78.6 (72.7, 84.5)	83.2 (80.1, 86.3)	82.8 (78.9, 86.8)	85.3 (80.8, 89.9)
Other Hispanic	74.6 (72.9, 76.3)	68.4 (58.1, 78.7)	70.5 (62.3, 78.8)	74.8 (69.5, 80.1)	72.2 (69.4, 75.1)	75.2 (71.8, 78.7)	70.0 (64.7, 75.2)	78.5 (74.8, 82.2)	80.0 (76.0, 84.1)
Non-Hispanic White	68.7 (67.7, 69.8)	65.2 (62.3, 68.0)	66.1 (62.8, 69.4)	67.2 (64.6, 69.9)	68.1 (65.0, 71.2)	68.7 (64.9, 72.5)	70.6 (69.0, 72.2)	71.5 (68.6, 74.3)	72.2 (68.6, 75.8)
Non-Hispanic Black	75.5 (74.4, 76.6)	75.8 (72.8, 78.7)	75.5 (72.0, 79.1)	73.0 (70.6, 75.4)	76.4 (73.3, 79.5)	76.2 (73.0, 79.4)	75.5 (72.2, 78.7)	75.0 (71.8, 78.1)	76.4 (73.6, 79.1)
Other race	54.1 (51.9, 56.3)	50.4 (42.2,58.6)	51.0 (40.9, 61.0)	49.2 (41.9, 56.5)	53.0 (45.8, 60.1)	47.3 (43.5, 51.1)	50.1 (44.3, 56.0)	55.8 (50.6, 61.0)	66.5 (63.1, 70.0)
Education									
Less than high school	71.8 (70.4, 73.2)	66.9 (61.8, 72.0)	67.8 (64.6, 71.0)	71.3 (68.5, 74.1)	75.0 (70.9, 79.1)	71.7 (67.7, 75.7)	73.7 (70.9, 76.4)	73.8 (69.1, 78.6)	74.7 (71.4, 78.0)
High school graduate	72.4 (71.2, 73.6)	69.5 (67.4, 71.6)	70.0 (66.3, 73.7)	69.9 (66.8, 72.9)	71.3 (68.3, 74.4)	73.1 (68.1, 78.1)	73.6 (70.5, 76.8)	77.3 (73.4, 81.2)	74.7 (71.6, 77.8)
Some college or AA	71.9 (70.7, 73.1)	68.1 (64.8, 71.3)	70.1 (66.8, 73.4)	69.0 (66.2, 71.8)	70.2 (66.6, 73.8)	70.5 (65.8, 75.2)	74.4 (72.4, 76.5)	74.7 (71.8, 77.6)	76.9 (73.6, 80.1)

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degree									
College graduate or above	63.6 (62.0, 65.2)	60.0 (55.0, 65.0)	60.4 (55.2,65.7)	62.3 (58.1, 66.5)	62.6 (57.3, 68.0)	63.8 (58.6, 69.0)	63.0 (59.7, 66.2)	64.5 (60.2, 68.9)	69.5 (65.0, 74.0)
Poverty income ratio									
< 130%	68.8 (67.4, 70.3)	62.6 (59.1, 66.1)	67.3 (63.1, 71.6)	67.1 (63.9, 70.4)	71.1 (66.3, 75.8)	68.4 (64.2, 72.7)	69.1 (65.9, 72.4)	72.6 (68.1, 77.2)	71.0 (67.1, 74.9)
≥ 130%	69.9 (68.9, 70.9)	67.3 (64.8, 69.8)	67.2 (64.1, 70.4)	68.3 (66.5, 70.2)	68.8 (65.9, 71.6)	69.3 (65.6, 73.0)	71.3 (69.1, 73.6)	71.6 (68.2, 75.0)	74.9 (72.3, 77.4)
Physical activity									
Inactive	75.6 (74.3, 76.9)	67.8 (59.4, 76.0)	74.2 (66.0, 82.6)	71.7 (69.5, 74.0)	76.3 (73.4, 79.2)	63.2 (56.5, 69.9)	78.4 (75.4, 81.5)	77.6 (73.8, 81.4)	78.3 (75.4, 81.2)
Insufficiently active	69.7 (68.1, 71.3)	68.3 (66.1, 70.5)	68.2 (63.6, 72.7)	69.4 (65.9, 73.0)	68.1 (64.1, 72.1)	59.6 (53.1, 66.1)	71.0 (66.0, 76.0)	76.0 (70.1, 81.8)	81.1 (77.8, 84.4)
Sufficiently active	67.9 (66.7, 69.1)	60.9 (56.1, 65.7)	62.0 (58.2, 65.7)	66.4 (63.9, 68.8)	66.7 (62.9, 70.4)	70.8 (67.6, 74.0)	67.4 (65.4, 69.4)	69.3 (66.3, 72.2)	71.1 (67.8, 74.5)

[a] Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003–2018).

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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eTable 4. Change in mean BMI by sex among adults in the United States, 2003-2018

Years	Weighted mean BMI					
	Men		Women		Both	
	Adjusted β [a] (95%CI)	p-value	Adjusted β [a] (95%CI)	p-value	Adjusted β [a] (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	0.38 (-0.29,1.06)	0.259	0.44 (-0.47, 1.35)	0.338	0.38 (-0.23,0.99)	0.215
2007 - 2008	0.42 (-0.14,0.97)	0.139	0.52 (-0.10, 1.15)	0.102	0.48 (0.04,0.93)	0.035
2009 - 2010	0.72 (0.09,1.35)	0.025	0.64 (0.04, 1.23)	0.037	0.70 (0.26,1.15)	0.002
2011 - 2012	0.64 (0.04, 1.23)	0.035	1.50 (0.84, 2.16)	<0.001	1.08 (0.55, 1.61)	<0.001
2013 - 2014	0.73 (0.18, 1.28)	0.010	1.55 (0.78, 2.32)	<0.001	1.18 (0.66, 1.70)	<0.001
2015 - 2016	1.28 (0.62, 1.95)	<0.001	1.88 (1.15, 2.61)	<0.001	1.59 (1.03, 2.20)	<0.001
2017 - 2018	1.62 (1.00, 2.24)	<0.001	2.26 (1.30, 3.21)	<0.001	1.96 (1.34, 2.57)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: CI, confidence interval.

[a] Models adjusted for age, sex , race, education, family poverty income ratio, total energy intake and physical activity status.

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eTable 5. Change in prevalence of obesity by sex among adults in the United States, 2003-2018

Years	Prevalence of obesity					
	Men		Women		Both	
	Adjusted OR [a] (95%CI)	p-value	Adjusted OR [a] (95%CI)	p-value	Adjusted OR [a] (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	1.03 (0.96, 1.09)	0.402	1.04 (0.98, 1.09)	0.197	1.03 (0.99, 1.07)	0.184
2007 - 2008	1.03 (0.98, 1.08)	0.229	1.03 (0.99, 1.07)	0.193	1.03 (1.00, 1.06)	0.084
2009 - 2010	1.07 (1.02, 1.13)	0.008	1.04 (1.01, 1.08)	0.026	1.06 (1.03, 1.09)	<0.001
2011 - 2012	1.06 (1.03, 1.11)	0.028	1.08 (1.04, 1.13)	<0.001	1.07 (1.03, 1.11)	<0.001
2013 - 2014	1.06 (1.01, 1.11)	0.011	1.08 (1.05, 1.14)	<0.001	1.08 (1.04, 1.11)	<0.001
2015 - 2016	1.11 (1.04, 1.18)	<0.001	1.12 (1.07, 1.17)	<0.001	1.11 (1.07, 1.16)	<0.001
2017 - 2018	1.17 (1.09, 1.24)	<0.001	1.14 (1.08, 1.21)	<0.001	1.15 (1.10, 1.21)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: CI, confidence interval; OR, odds ratio.

Crude model: we did not adjust other covariants.

[a] Models adjusted for age, sex , race, education, family poverty income ratio, total energy intake and physical activity status.

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eTable 6. Change in prevalence of overweight by sex among adults in the United States, 2003-2018

Years	Prevalence of overweight					
	Men		Women		Both	
	Adjusted OR [a] (95%CI)	p-value	Adjusted OR [a] (95%CI)	p-value	Adjusted OR [a] (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	1.01 (0.96, 1.06)	0.580	1.01 (0.95, 1.08)	0.690	1.01 (0.97, 1.05)	0.598
2007 - 2008	1.00 (0.96, 1.05)	0.868	1.03 (0.98, 1.08)	0.206	1.02 (0.98, 1.05)	0.281
2009 - 2010	1.02 (0.97, 1.08)	0.406	1.03 (0.98, 1.08)	0.248	1.03 (0.99, 1.07)	0.178
2011 - 2012	1.01 (0.96, 1.06)	0.819	1.08 (1.03, 1.14)	0.002	1.05 (1.00, 1.09)	0.034
2013 - 2014	1.02 (0.98, 1.07)	0.370	1.07 (1.02, 1.12)	0.010	1.05 (1.01, 1.08)	0.012
2015 - 2016	1.03 (0.98, 1.08)	0.305	1.09 (1.04, 1.15)	0.001	1.06 (1.02,1.10)	0.005
2017 - 2018	1.05 (1.00, 1.11)	0.050	1.11 (1.05, 1.17)	<0.001	1.08 (1.04, 1.13)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: CI, confidence interval; OR, odds ratio.

[a] Models adjusted for age, sex , race, education, family poverty income ratio, total energy intake and physical activity status.

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STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2,3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6,7*
Bias	9	Describe any efforts to address potential sources of bias	6,7
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	7,8
		(*c*) Explain how missing data were addressed	7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	7,8

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		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8,9
		(b) Indicate number of participants with missing data for each variable of interest	8,9
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	8,9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9,10,11
		(*b*) Report category boundaries when continuous variables were categorized	9,10,11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13,14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14,15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Trends in body mass index, overweight and obesity among adults in the United States, NHANES 2003 to 2018: a repeat cross-sectional survey

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Trends in body mass index, overweight and obesity among adults in the United States, NHANES 2003 to 2018: a repeat cross-sectional survey

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Abstract

Objectives: To analyze detailed trends in adult obesity from 2003 through 2018, and provide the latest national estimates of adult obesity 2017-2018.

Design, Setting ,and Participants: Analysis of data including measured height and weight obtained from 42,266 adults aged ≥ 20 years in the National Health and Nutrition Examination Survey, a cross-sectional, nationally representative sample of the US population.

Exposure: Survey period.

Primary Outcome Measures: The mean body mass index and the prevalence of overweight and obesity.

Results: In 2017-2018, the prevalence of overweight (including obesity, BMI ≥ 25 kg/m^2) and obesity (BMI ≥ 30 kg/m^2) was 73.8% (95% CI, 71.1%-76.4%) and 42.8% (95% CI, 39.5%-46.1%), respectively. From 2003-2004 through 2017-2018, a significant increase in the prevalence of overweight (overall adjusted OR for 2017-2018 vs 2003-2004, 1.08 [95% CI, 1.04-1.13]) and obesity (overall adjusted OR for 2017-2018 vs 2003-2004, 1.15 [95% CI, 1.10-1.21]) was found among American adults. However, annual changes in mean BMI, the prevalence of overweight and obesity did not differ significantly before and after 2009-2010. The prevalence of overweight and obesity varied significantly by age, sex, race, education, daily total energy intake, economic conditions, and physical activity status (all P<0.05). A higher prevalence of obesity was found among older adults (aged 60-69 years), women, Non-Hispanic Blacks, and participants who were non-college educated, physically inactive, reported lower daily total energy intake, and had poor economic status.

Conclusions: Although the prevalence of adult obesity continues to rise, there have been no significant changes in the rising rate of adult obesity prevalence between 2003-2004 and 2017-2018. In 2017-

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2018, the prevalence of obesity was 42.8%, which puts 76 million Americans at risk for serious and costly chronic conditions. The prevalence of overweight and obesity varied significantly by age, sex, race, education, daily total energy intake, economic conditions, and physical activity status.

Keywords: American adults; body mass index; overweight/obesity; trends; NHANES

Strengths and limitations of this study

1. Our present study used a larger sample size as well as a longer time span.

2. Although NHANES is designed to provide nationally representative estimates, it is a repeated cross-sectional survey, which precludes within-individual change in BMI or obesity.

3. Our study assessed annual change in BMI and obesity, and the potential effects of the financial crisis around 2009 among US adults.

4. Obesity was defined mainly based on measurements of BMI, which does not measure body fat directly.

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1. Introduction

Obesity is one of the most common risk factors for chronic diseases such as diabetes mellitus, cardiovascular diseases, renal damage, and cancers that affects 670 million adults globally in 2016[1-7]. In the United States, the obesity rate has been on the rise since the 1980s[8]. By 2030, obesity is expected to reach a prevalence of 48.9% among American adults[9].

Some studies have reported on trends in obesity prevalence among American adults using the National Health and Nutrition Examination Survey (NHANES) data[8, 10-19]. Between 1976-1980 and 1988-1994, obesity prevalence among American adults increased from 14.5% to 22.5%[10]. The prevalence of obesity increased from 22.9% to 30.5% from 1988-1994 through 1999-2000, maintaining similar growth rates of about 8%[11]. Over the period 1999-2000 to 2017-2018, there were larger changes in the prevalence among men (from 27.5% to 43.0%) than seen previously and similar growth in prevalence among women (from 33.4% to 41.9%).[14] Most of the previous studies focused on differences in the prevalence of obesity by age, sex, and race. The differences in the prevalence of obesity by other covariates such as educational status, economic status, total daily energy intake, and physical activity status have been scarcely studied. The effects of the 2008–2009 global financial crisis on economic status, physical activity status, and daily total energy intake are still unknown. How these changes in economic status, physical activity status, and daily total energy intake may impact on the prevalence of overweight and obesity are less well understood.

In this study, our primary aim was to provide the latest national estimates of adult obesity and evaluate trends in mean body mass index(BMI) and adult obesity between 2003-2004 and 2017-2018. The secondary aims of our study were as follows: (1) To explore the changes in mean BMI and adult obesity before and after 2009 (The 2008–2009 global financial crisis taken place). (2) To assess how

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these trends might vary by age, sex, race, educational status, economic status, total daily energy intake, and physical activity status.

2. Materials and methods

2.1 Database and participants

The NHANES is a nationally representative sample of the United States population, which collects data from survey participants through household interviews, standardized physical examinations, and laboratory tests in mobile examination centers[20]. The survey is unique in that it combines interviews and physical examinations. The NHANES released data every 2 years to ensure an adequate sample size for analyses and protect confidentiality. The survey examines a nationally representative sample of about 5,000 people each year. The NHANES interview includes demographic, socioeconomic, dietary, and health-related questions. The examination component consists of medical, dental, and physiological measurements, as well as laboratory tests administered by highly trained medical personnel. Detailed information on the NHANES procedures is available in the literature.[21]

The present study used NHANES data including adults aged ≥ 20 years (N = 44,790) collected between 2003-2004 and 2017-2018 with 8 survey cycles. Among the 44,790 participants (21,668 men and 23,122 women), 42,266 had complete data on BMI, and were included in the final analysis.

2.2 Data collection

Information about anthropometric measurements (including height and weight) and BMI was obtained from examination data. Information about age, sex, race, education, and poverty income ratio (PIR) was obtained from demographic data. Data on total energy intake was obtained from the total nutrient intake file (second-day dietary interview), which contains a summary of an individual's nutrition from all foods and beverages provided on the dietary recall. Total energy intake was

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categorized into tertiles. PIR was a ratio of family income to poverty threshold, which was calculated by dividing family income by the poverty guidelines for the survey year. PIR was categorized into two groups: <130% and ≥ 130%. This classification of PIR has been used in a previous study.[22] Data on physical activity was obtained from the physical activity questionnaire. Based on the 2018 Physical Activity Guidelines for Americans, respondents who engaged in moderate-intensity aerobic activity for 150 min/week or vigorous-intensity aerobic activity for 75 min/week, or an equivalent combination of both (1 min of vigorous-intensity physical activity is equivalent to 2 min of moderate intensity physical activity) were defined as meeting the guidelines.[23] In our analysis, physical activity was categorized into three levels: sufficiently active, insufficiently active, and inactive. Sufficiently active was defined as a moderate-intensity aerobic activity for 150 min/week or vigorous-intensity aerobic activity for 75 min/week, or an equivalent combination of both. Insufficiently active was defined as some aerobic activity but not enough to meet the guidelines (10-149 min/week). Inactive was defined as some physical activity (< 10 min/week) or reported no physical activity.[23] This classification of physical activity has been used in previous studies.[24]

2.3 Statistical analysis

According to WHO classification, we defined overweight, including obesity, as BMI ≥ 25 kg/m^2; and obesity as ≥ 30 kg/m^2. Overall, the mean BMI and prevalence of overweight and obesity in each survey cycle were calculated incorporating sample weights and adjusted for clusters and strata of the complex sample design of the NHANES. Individuals with missing demographic information on height or weight measurements are excluded from the analyses.

In table 1, continuous variables were presented as weighted means and standard errors, while categorical variables were presented as unweighted counts and weighted proportions. Comparisons

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between survey cycles were made using the wald-test (categorical variables) or Kruskal-Wallis rank-sum test (skewed distribution).

We used survey-weighted generalized linear regression models to evaluate the trends in BMI, overweight and obesity by survey period. Multivariate survey-weighted generalized linear regression models were adjusted for age, sex, race, education, PIR, total energy intake, and activity status. A p-value for trend was obtained by entering the median value of each category of BMI, the prevalence of overweight and obesity as a continuous variable in the models, and rerunning the corresponding survey-weighted generalized linear regression models.

We used a previously described method to compare trends in mean BMI, overweight and obesity before and after 2009-2010 to explore the potential impact of the financial crisis around 2008.[25] We calculated mean BMI annual changes as the absolute value of the difference in mean BMI between the start and end years divided by the total number of years covered. We also calculated the annual relative changes in overweight and obesity prevalence as the absolute value of the difference in prevalence between the start and end years divided by the prevalence in the start year annualized by accounting for compounding. Welch's t-tests were used to compare trends in mean BMI, overweight and obesity before and after 2009-2010.

All simulations and analyses were performed using R software (R Foundation for Statistical Computing, Vienna, Austria, Version 3.6.3) and the "survey" package (e.g., svymean and svyglm), which considers sampling weights (16-year exam weight), clustering, and stratification of the complex survey design.[26] A two-sided p-value <0.05 was considered to be statistically significant.

2.4 Patient and Public Involvement

Approval was obtained from the National Center for Health Statistics Research Ethics Review

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Board, and all participants provided written informed consent. Therefore, there was no need for any ethical consent in this study.

3. Results

The demographic characteristics of all participants according to survey year cycles are listed in Table 1. In total, 42,266 participants (20,408 men and 21,858 women) were included in our final analysis. The mean (SE) age of the weighted population was 47.11 (0.20) years, 47.97% of the population were men, and the weighted mean (SE) BMI was 28.93 (0.07) kg/m^2. Approximately two-thirds (67.36%) were Non-Hispanic White, 11.41% were Non-Hispanic Black, 8.38% were Mexican American, 5.33% were Hispanic and 7.51% were "other race". More than 80% had a minimum of high school education. Approximately 80% reported good economic status (PIR ≥ 130%). The average (SE) daily energy intake was 2027.31 (7.96) kcal. About 65% reported meeting physical activity guidelines. The prevalence of overweight and obesity increased overtime, whereas the inverse was true for normal weight ($p = 0.002$). The prevalence of overweight and obesity varied significantly by age, sex, race, education, daily total energy intake, economic conditions, and physical activity status(Table S1).

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Table 1. Baseline characteristics of participants. *

Characteristics	National Health and Nutrition Examination Survey cycles †								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Age, years	47.11 ± 0.20	46.02 ± 0.52	46.42 ± 0.74	46.55 ± 0.44	46.92 ± 0.49	47.21 ± 0.82	47.45 ± 0.38	47.92 ± 0.58	48.14 ± 0.53
Age, years (group)									
20 - 30	8,033 (20.5)	940 (21.0)	1,101 (20.5)	928 (20.5)	1,134 (21.1)	1,043 (20.6)	1,025 (20.6)	1,016 (20.2)	846 (19.7)
30 - 39	7,175 (18.4)	759 (20.3)	823 (19.8)	997 (19.1)	1,010 (18.1)	916 (17.5)	951 (17.4)	921 (17.4)	798 (19.0)
40 - 49	7,035 (19.4)	742 (21.6)	782 (21.2)	920 (21.2)	1,063 (19.8)	869 (19.4)	991 (18.9)	896 (17.7)	772 (16.3)
50 - 59	6,714 (18.1)	596 (16.6)	622 (16.9)	902 (17.8)	956 (18.2)	877 (18.9)	914 (18.1)	917 (18.8)	930 (19.3)
60 - 69	6,629 (12.8)	695 (10.2)	631 (11.0)	894 (11.0)	876 (12.0)	820 (13.5)	866 (14.1)	863 (14.5)	984 (15.1)
≥ 70	6,680 (10.8)	915 (10.5)	721 (10.3)	966 (10.5)	955 (10.8)	712 (10.1)	773 (11.0)	793 (11.4)	845 (11.6)
Sex, n (%)									
Male, n (%)	20,408 (48.0)	2,237 (48.1)	2,237 (48.2)	2,746 (48.0)	2,889 (48.1)	2,585 (48.1)	2,638 (48.0)	2,638 (47.6)	2,493 (47.7)
Female, n (%)	21,858 (52.0)	2,410 (51.9)	2,443 (51.8)	2.861 (52.0)	3,105 (51.9)	4,652 (51.9)	2,882 (52.0)	2,882 (52.4)	2,682 (52.3)
Race									
Mexican American	6,805 (8.4)	931 (8.0)	944 (8.0)	967(8.3)	1,096 (8.6)	509 (7.7)	737 (9.1)	936 (8.8)	685 (8.7)
Other Hispanic	3,755 (5.3)	139 (3.5)	148 (3.4)	629 (4.9)	610 (5.0)	538 (6.5)	488 (5.6)	720 (6.4)	483 (6.9)
Non-Hispanic White	18,120 (67.4)	2,464 (72.0)	2,338 (71.9)	2,625 (69.6)	2,865 (67.9)	1,917 (66.5)	2,366 (65.9)	1,767 (64.0)	1,778 (62.4)
Non-Hispanic Black	9,094 (11.4)	910 (11.2)	1,064 (11.4)	1,155 (11.2)	1,087 (11.4)	1,382 (11.5)	1,135 (11.5)	1,142 (11.4)	1,219 (11.5)
Other Race	4,492 (7.5)	203 (5.4)	186 (5.2)	231 (6.1)	336 (7.2)	891 (7.7)	794 (7.9)	841 (9.4)	1,010 (10.5)
Education, n (%)									
Less than high school	10,814 (16.4)	1,362 (18.1)	1,290 (17.4)	1,728 (20.3)	1,710 (18.9)	1,235 (16.4)	1,191 (15.2)	1,277 (14.3)	1,021 (11.0)
High school graduate	9,787 (23.6)	1,167 (27.1)	1,119 (25.0)	1,392 (25.4)	1,376 (22.9)	1,098 (19.8)	1,232 (21.6)	1,172 (20.8)	1,231 (27.0)

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Some college or AA degree	12,266 (31.4)	1,263 (31.5)	1,334 (31.3)	1,440 (29.0)	1,679 (30.3)	1,576 (32.4)	1,704 (32.9)	1,602 (32.5)	1,668 (30.8)
College graduate or above	9,345 (28.6)	847 (23.2)	931 (26.1)	1,041 (25.3)	1,216 (27.7)	1,324 (31.3)	1,389 (30.3)	1,352 (32.4)	1,245 (31.1)
Poverty income ratio, n (%)									
< 130%	12,129 (21.3)	1,264 (20.5)	1,167 (17.1)	1,552 (20.4)	1,817 (21.7)	1,724 (24.6)	1,762 (24.7)	1,568 (20.9)	1,275 (20.1)
≥ 130%	26,450 (78.7)	3,119 (79.5)	3,294 (82.9)	3,536 (79.6)	3,592 (78.3)	3,078 (75.4)	3,335 (75.3)	3,280 (79.1)	3,216 (79.9)
BMI, kg/m^2	28.93 ± 0.07	28.24 ± 0.15	28.57 ± 0.23	28.54 ± 0.16	28.75 ± 0.13	28.73 ± 0.21	29.17 ± 0.17	29.42 ± 0.25	29.86 ± 0.26
BMI, kg/m^2 (group)									
< 25	12,522 (30.7)	1,480 (33.7)	1,432 (32.9)	1,628 (32.0)	1,684 (30.9)	1,714 (31.7)	1,700 (30.0)	1,517 (28.7)	1,367 (26.9)
25 - 30	14,046 (32.9)	1,632 (34.1)	1,608 (32.9)	1,934 (34.3)	2,030 (33.4)	1,677 (33.8)	1,767 (32.6)	1,731 (31.9)	1,667 (30.8)
≥ 30	15,698 (36.4)	1,535 (32.2)	1,640 (34.2)	2,045 (33.7)	2,280 (35.8)	1,846 (34.6)	2,053 (37.4)	2,158 (39.4)	2,141 (42.3)
Total energy intake, Kcal/d	2,027.31±7.96	2,113.90 ± 13.81	2,051.01 ± 25.07	2016.62 ± 20.87	2061.43±27.10	2014.61 ± 18.59	2017.22 ± 23.24	1970.20 ± 23.28	1980.34 ± 23.18
Physical activity, n (%)									
Inactive	8,504 (18.1)	150 (5.6)	142 (4.4)	1,656 (23.1)	1,711 (23.7)	355 (6.8)	1,562 (26.3)	1,565 (23.0)	1,363 (21.2)
Insufficiently active	6,649 (17.5)	1,380 (50.2)	1,403 (47.5)	734 (13.0)	817 (13.7)	536 (10.3)	568 (9.7)	567 (9.9)	644 (11.3)
Sufficiently active	23,320 (64.4)	1,156 (44.2)	1,303 (48.2)	3,217 (63.8)	3,466 (62.7)	4,346 (82.9)	3,390 (64.0)	3,274 (67.1)	3,168 (67.5)

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003-2018).

† Values are presented as mean ± SE for continuous variables and unweighted numbers (weighted %) for categorical variables.

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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The mean (SE) BMI levels rose from 28.24 (0.07) kg/m^2 in 2003-2004 to 29.86(0.26) kg/m^2 in 2017-2018 (Table S2). In 2017-2018, the obesity prevalence was 42.8% (95% CI 39.5-46.1), increasing more than 10% compared with 2003-2004 (32.3%, 95% CI 29.9-34.6) (Table S3). Consistent with the increase in mean BMI and obesity prevalence, we found that the prevalence of overweight rose from 66.3% (95% CI 64.4-68.3) in 2003-2004 to 73.8 (95% CI 71.1-76.4) in 2017-2018 (Table S4). We used survey-weighted generalized linear regression models to evaluate the trends in BMI, overweight and obesity by survey period (Table 2). Compared with 2003-2004, the mean (SE) BMI increased by 1.96 kg/m^2 (95% CI 1.34-2.57, $p < .001$) in 2017-2018 after adjusting for age, sex, race, education, PIR, and activity status (Table 2, Table S5). The findings were similar for the prevalence of overweight and obesity. Compared with 2003-2004, the adjusted odd ratios for the prevalence of overweight and obesity were 1.08 (95% CI 1.04-1.13, $p < .001$) and 1.15 (95% CI 1.10-1.21, $p < .001$), respectively (Table 2, Table S6, Table S7). However, we found no significant effect of the survey cycle on the prevalence of overweight among men after adjusting for potential confounding variables (adjusted odd ratio 1.05, 95%CI 1.00-1.11, $p = 0.050$) (Table S7).

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Table 2. Change in BMI, overweight and obesity overtime among adults in the United States, 2003-2018

Years	Mean BMI		Prevalence of overweight		Prevalence of obesity	
	Adjusted β * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	0.38 (-0.23,0.99)	0.215	1.01 (0.97, 1.05)	0.598	1.03 (0.99, 1.07)	0.184
2007 - 2008	0.48 (0.04,0.93)	0.035	1.02 (0.98, 1.05)	0.281	1.03 (1.00, 1.06)	0.084
2009 - 2010	0.70 (0.26,1.15)	0.002	1.03 (0.99, 1.07)	0.178	1.06 (1.03, 1.09)	<0.001
2011 - 2012	1.08 (0.55, 1.61)	<0.001	1.05 (1.00, 1.09)	0.034	1.07 (1.03, 1.11)	<0.001
2013 - 2014	1.18 (0.66, 1.70)	<0.001	1.05 (1.01, 1.08)	0.012	1.08 (1.04, 1.11)	<0.001
2015 - 2016	1.59 (1.03, 2.20)	<0.001	1.06 (1.02,1.10)	0.005	1.11 (1.07, 1.16)	<0.001
2017 - 2018	1.96 (1.34, 2.57)	<0.001	1.08 (1.04, 1.13)	<0.001	1.15 (1.10, 1.21)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio.

* Models adjusted for age, sex, race, education, family poverty income ratio, total energy intake and physical activity status.

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Table 3 shows the annual change in mean BMI as well as overweight and obesity prevalence during 2003-2004 to 2009-2010 and 2011-2012 to 2017-2018. The increase of mean BMI was somewhat bigger after 2009-2010 (0.12 kg/m^2 annual relative increase, 95% CI 0.06-0.19) compared with before 2009-2010 (0.07 kg/m^2 annual relative increase, 95% CI 0.02-0.13). But this difference was not statistically significant (p = 0.848). Annual changes in the prevalence of overweight and obesity were similar. The acceleration in the rise of obesity prevalence was mainly due to an increase in the prevalence of obesity among those who are in a better economic position (0.40% annual relative increase, 95% CI -1.11-1.93 vs 2.97% annual relative increase, 95% CI 1.75-4.20). Again, this difference was not statistically different (p=0.985). Likewise, for the prevalence of overweight, the annual increase was also numerically faster after 2009-2010 compared with before 2009-2010 (0.6%, 95% CI -0.08-1.27 vs 0.72%, 0.15-1.29; p = 0·584). Remarkably, the prevalence of overweight was nearly unchanged among those with poor economic conditions after 2009-2010 (0.00 annual relative increase, 95% CI -0.96-0.97) compared with before 2009-2010 (1.82 annual relative increase, 95% CI 0.55-3.10, p = 0.037). Meanwhile, both men and women with poor economic conditions slowed down the increase of BMI and the prevalence of overweight and obesity after 2009-2010 compared with before 2009-2010. In contrast, a bigger increase was found among those with good economic conditions after 2009-2010, although without statistical significance (p > 0.05).

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Table3. Annual change in BMI, overweight, obesity and economic status during 2003-2010 and 2011–2018

Characteristic	Men			Women			Both		
	2003/04-2009/2010	2011/12-2017/2018	p-value*	2003/2004-2009/2010	2011/2012-2017/2018	p-value*	2003/2004-2009/2010	2011/2012-2017/2018	p-value*
Change (95% CI) in mean BMI (kg/m²)									
Overall	0.07 (0.02, 0.13)	0.12 (0.06, 0.19)	0.848	0.65 (-0.01, 0.14)	0.13 (-0.39, 2.76)	0.846	0.07 (0.02, 0.13)	0.12 (0.06, 0.19)	0.848
PIR<130%	0.17 (0.02, 0.32)	0.08 (-0.06, 0.22)	0.245	0.17 (0.04, 0.30)	0.06 (-0.09, 0.21)	0.186	0.17 (0.05, 0.28)	0.07 (-0.04, 0.18)	0.170
PIR⩾130%	0.07 (-0.01, 0.14)	0.11 (0.04, 0.17)	0.716	0.15 (-0.04, 0.13)	0.16 (0.07, 0.25)	0.943	0.06 (0.00, 0.11)	0.13 (0.07, 0.20)	0.922
Percentage change (95% CI) in overweight prevalence									
Overall	0.69 (-0.18, 1.56)	0.50 (-0.24, 1.24)	0.393	0.50 (-0.45, 1.47)	0.95 (0.30, 1.60)	0.746	0.60 (-0.08, 1.27)	0.72 (0.15, 1.29)	0.584
PIR<130%	2.64 (-0.52, 4.82)	-0.06 (-1.60, 1.50)	0.050	1.33 (0.10, 2.56)	0.03 (-0.97, 1.04)	0.096	1.82 (0.55, 3.10)	0.00 (-0.96, 0.97)	**0.037**
PIR⩾130%	0.36 (-0.59, 1.31)	0.64 (-0.03, 1.33)	0.646	0.28 (-0.81, 1.40)	1.31 (0.55, 2.08)	0.900	0.30 (-0.50, 1.10)	0.95 (0.34, 1.56)	0.844
Percentage change (95% CI) in obesity prevalence									
Overall	1.93 (0.10, 3.76)	2.29 (0.54, 4.02)	0.589	1.15 (-0.39, 2.76)	1.71 (0.56, 2.84)	0.699	1.51 (0.24, 2.81)	1.99 (0.93, 3.04)	0.689
PIR<130%	3.16 (0.12, 6.19)	2.38 (-0.48, 5.25)	0.378	2.38 (0.34, 4.46)	0.95 (-0.77, 2.67)	0.192	2.56 (0.81, 4.31)	1.47 (0.00, 2.95)	0.223
PIR⩾130%	1.93 (-0.03, 3.85)	2.08 (-0.38, 3.77)	0.536	0.97 (-1.00, 3.00)	2.21 (0.62, 3.78)	0.796	0.40 (-1.11, 1.93)	2.97 (1.75, 4.20)	0.985

Abbreviations: BMI, body mass index; CI, confidence interval; PIR poverty income ratio.

* p-value for difference in annual changes for 2004-2010 versus 2011-2018.

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Graphical representations of the changes in the distribution of mean BMI, overweight and obesity prevalence are shown in Figure1 and Figure2. Figure 1 shows the changes in mean BMI across years stratified by age, PIR, educationin, and race. Similar trends in mean BMI were found across subgroups of age, PIR, education, race, sex, and activity status. Overall, the mean BMI generally increased overtime among all participants. In the age subgroup, the lowest mean BMI was found in those aged 20–30 years, followed by those aged > 70 years (Table S2, Figure1). Compared to good economic conditions, BMI was higher for those with poor economic conditions since 2005-2006. In 2017-2018, participants with poor economic conditions had a mean BMI of 1.68 kg/m^2 lower than those with good economic conditions. Between 2003-2004 and 2017-2018, lower mean BMI was found among participants with a higher educational level than among those with a lower educational level. A similar trend was found in the subgroup stratified by race. In 2017-2018, the mean (SE) BMI for all participants was 29.86 ± 0.26 kg/m^2, with the highest mean BMI in Non-Hispanic Blacks (31.29 ± 0.29) and the lowest BMI in other race populations (28.21 ± 0.39) (Table1, Figure1). Figure 2 shows the changes in mean BMI across years stratified by sex and activity status. Changes in overweight and obesity prevalence across years stratified by sex are also shown in Figure 2. From 2003-2004 to 2017-2018, the mean BMI rose similarly in both sexes, by about 1.61 kg/m^2 totally for men and 1.64 kg/m^2 for women (Table S2, Figure2). Meanwhile, men had a lower BMI than women. In the activity status subgroup, there was a more complex pattern, with a decrease in mean BMI in 2011-2012 among those who were inactive and insufficiently active. Although there was an acceleration in the rise of mean BMI among those who were sufficiently active, their mean BMI was the lowest.

The trends in increasing obesity prevalence overtime were largely consistent for men and women. In 2003-2004, men had lower mean BMI and lower prevalence of obesity than women, but a reversed

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pattern was seen in 2017-2018. In 2017-2018, men had a higher prevalence of obesity than women (43.3%, 95% CI 38.2-48.4 vs 42.3%, 38.6-46.0) (Table S3, Figure2).

The trends in increasing overweight prevalence overtime were similar for both sexes. Overall, the overweight prevalence in men was higher than in women. Between 2003-2004 and 2017-2018, the overweight rose similarly in both sexes, by about 1.61 kg/m^2 totally for men and 1.64 kg/m^2 for women. As for overweight prevalence trends, there was increasing prevalence of men from 70.6% (95%CI 68.0-73.0) in 2003-20044 to 77.4% (95%CI 73.9-80.9) in 2017-2018, and of women from 62.5% (95%CI 59.9-65.9) to 70.5% (95%CI 67.3-73.6) (Table S4, Figure2).

4.Discussion

Our present study showed that the prevalence of obesity among American adults increased from 32.3% in 2003-2004 to 42.8% in 2017-2018. These results are broadly consistent with the results reported by National Center for Health Statistics (NCHS). For the years 2017-2018, the prevalence of obesity was 42.3% among men and 43.3% among women. Compared with 2003-2004, the mean BMI increased by 1.94 kg/m^2, by 15% for obesity prevalence, and by 8% for overweight prevalence in 2017-2018 after adjusting for age, sex, race, education, PIR, and activity status. The rises in mean BMI and the prevalence of both overweight and obesity were somewhat bigger after 2009-2010 compared with before 2009-2010. However, the difference was not statistically significant.

The levels and changes in trends of mean BMI and obesity prevalence among American adults have been covered by numerous studies.[9, 15, 27-29] The NCHS reported that the age-adjusted obesity prevalence among adults was 42.4% in 2017-2018, and obesity prevalence increased among adults from 1999-2000 through 2017-2018.[15] Another study using data from the 2005–2014 NHANES also showed that a statistically significant positive linear trend in obesity prevalence were

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present in women but not in men.[28] One recent study suggested that the prevalence of obesity among US adults rose from 35.4% in 2011-2012 to 43.4% in 2017-2018. From 2011-2012 through 2017-2018, the mean BMI rose from 28.7 kg/m^2 to 29.8 kg/m^2.[29] Our results were broadly consistent with the results of the above studies at each timepoint. However, our present study used a larger sample size as well as a longer time span.

To the best of our knowledge, few studies have assessed annual change in BMI and obesity and the potential effects of the financial crisis around 2009 among US adults. A previous study conducted using NHANES data 1999–2008 showed that the increases in the prevalence of obesity do not appear to be continuing at the same rate from 1999-2000 through 2007-2008. When they adjusted for age and race group with survey period as a categorical variable, there were no significant differences in the prevalence of obesity between 2003-2004 and 2007-2008 for men.[27] This is broadly consistent with our findings. In our study, statistically significant differences in mean BMI and obesity prevalence for both sexes were found since 2009-2010 (Table 2). Furthermore, a previous study evaluated the effects of the economic crisis on dietary quality and obesity rates.[30] They found that economic changes can modify diet quality and increase the risk to have a poor diet or being obese, which was mainly due to the changes in economic and work conditions. In our study, the impact of economic conditions on BMI was complex. A significant increase in mean BMI was found among both the poor and the rich. The overall BMI was higher for those with poor economic conditions since 2005-2006 compared to good economic conditions (Figure 1). However, the acceleration in the rise of obesity prevalence was mainly due to an increase in the prevalence of obesity among those who are in a better economic position (Table 3). Interestingly, there was no statistical difference in annual change in obesity prevalence before and after the financial crisis. This may be mainly due to the increase in the proportion of the

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poor after the financial crisis. The proportion of the poor increased from 21.68% in 2009-2010 to 24.6% in 2011-2012. This trend continued until 2015. In our present study, although the differences were not statistically significant, numerical larger increases in mean BMI and the prevalence of both overweight and obesity were found after 2009-2010 compared with before 2009-2010.

Interestingly, participants in the highest daily total energy intake tertile had the lowest BMIs compared with those in the lowest daily total energy intake tertile (28.97 kg/m^2 vs. 29.30 kg/m^2). The findings were similar for the prevalence of obesity (36.7% vs. 39.9%) and overweight (69.8% vs. 70.9%). Thus, we analyzed the characteristics of the participants according to tertiles of daily total energy intake (Table S8). Compared with those in the lowest daily total energy intake tertile, participants in the highest daily total energy intake tertile had higher proportions of Non-Hispanic Whites and individuals who were college educated (college degree or higher), sufficiently physically active, and had good economic status. This might in part be related to the lower BMI and prevalence of obesity.

In addition, although the mean BMI and the prevalence of overweight and obesity increased overtime, the mean daily intake of energy decreased from 2003-2004 to 2017-2018 (2,113.90±7.96 Kcal/d vs 1,980.34±7.96 Kcal/d, $p < 0.001$). Several mechanisms may explain this phenomenon: (1) The reduction in energy intake may lead to hunger increases and energy expenditure declines-physiological adaptations that tend to push body weight back up.[31] (2) In the US, carbohydrate intake has increased markedly, resulting in major increases in the proportion of calories from carbohydrates.[32] A high-carbohydrate diet could produce postprandial hyperinsulinemia, which promotes energy storage and causes an increase in body weight.[33]

In our study, lower mean BMI was found among participants with a higher educational level than

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among those with a lower educational level. A previous study showed that a higher educational level is related to a lower BMI level among mid-age women, mainly on account of selection.[34] Theories of selection note that low-BMI children tend to have higher grades and test scores, and better chances of completing secondary and tertiary education. It is also reported that young overweight/obese women were more likely to have a lower educational level.[34] It might be explained by the following reasons: (1) Children with a lower BMI tend to come from socioeconomically advantaged families, and have better chances of completing their studies.[34] (2) Children with a lower BMI may benefit from physical activity, which may have a positive influence on academic performance.[35] (3) Negative views on high-BMI children may impair their academic performance.[36] Our results also show that women had a higher prevalence of obesity than men. This may be due to estrogen-reducing postprandial fatty acid oxidation, leading to an increase in body fat.[37] Meanwhile, It was less likely for women to be physically active than for men.

In our study, about 67.4% reported meeting physical activity guidelines in 2017-2018. As reported by National Center for Health Statistics (NCHS), 53.3% of adults aged 18 and over met the Physical Activity Guidelines for aerobic physical activity in 2018. However, the NCHS estimates were limited to leisure-time physical activity only. Our estimates were based on the Global Physical Activity Questionnaire, including both daily activities (work activities) and leisure time activities. For this reason, our estimates were larger than those reported by NCHS reports.

Although NHANES is designed to provide nationally representative estimates, it is a repeated cross-sectional survey, which precludes within-individual change in BMI or obesity. Meanwhile, obesity was defined mainly based on measurements of BMI, which does not measure body fat directly. Although BMI is highly correlated with overall body fat[38], the relationship between BMI and body

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fat varies by sex, age, and race-ethnicity[39]. In addition, the study used a large nationally representative sample of adults from the United States. Thus, our results are only generalizable to the US population. Therefore, there are certain limitations in the extrapolation of the study results.

The COVID-19 global pandemic has changed the lifestyle of most Americans. It has been reported that approaches designed to contain the spread of COVID-19 such as lockdowns might exacerbate the prevalence of obesity.[40] The effects of the COVID-19 global pandemic on BMI and the prevalence of obesity are yet to be examined. Regrettably, information about anthropometric measurements in NHANES after 2018 has not been released. Additional follow-up studies are required to answer these questions.

5. Conclusions

Although the prevalence of adult obesity continues to rise, there have been no significant changes in the rising rate of adult obesity prevalence between 2003-2004 and 2017-2018. In 2017-2018, the prevalence of obesity was 42.8%, which puts 76 million Americans at risk for serious and costly chronic conditions. The prevalence of overweight and obesity varied significantly by age, sex, race, education, daily total energy intake, economic conditions, and physical activity status.

Author contributions:

WG, ZL: designed the research; ZL and ML: analyzed the data; ZL: wrote the paper; ZL: had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis; WG, ZL, ML, and SW: assisted with interpretation of the results and critically reviewed the manuscript; and all authors: read and approved the final manuscript. The authors report no conflicts of interest.

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Competing interests statement

None.

Data sharing statement

Data described in the article are publicly and freely available without restriction at https://www.cdc.gov/nchs/nhanes/index.htm.

Ethics approval

Approval was obtained from the National Center for Health Statistics Research Ethics Review Board, and all participants provided written informed consent (Approval number: Protocol#98-12, #2005-06, #11-17, #18-01, https://www.cdc.gov/nchs/nhanes/irba98.htm).

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Figure legends

Figure1 Mean BMI by age (A), poverty income ratio (B), education (C) and race (D) group from 2003 to 2018.

Figure2 Mean BMI by sex (A), activity status (B)group and prevalence of overweight (C) and obesity (D) from 2003 to 2018.

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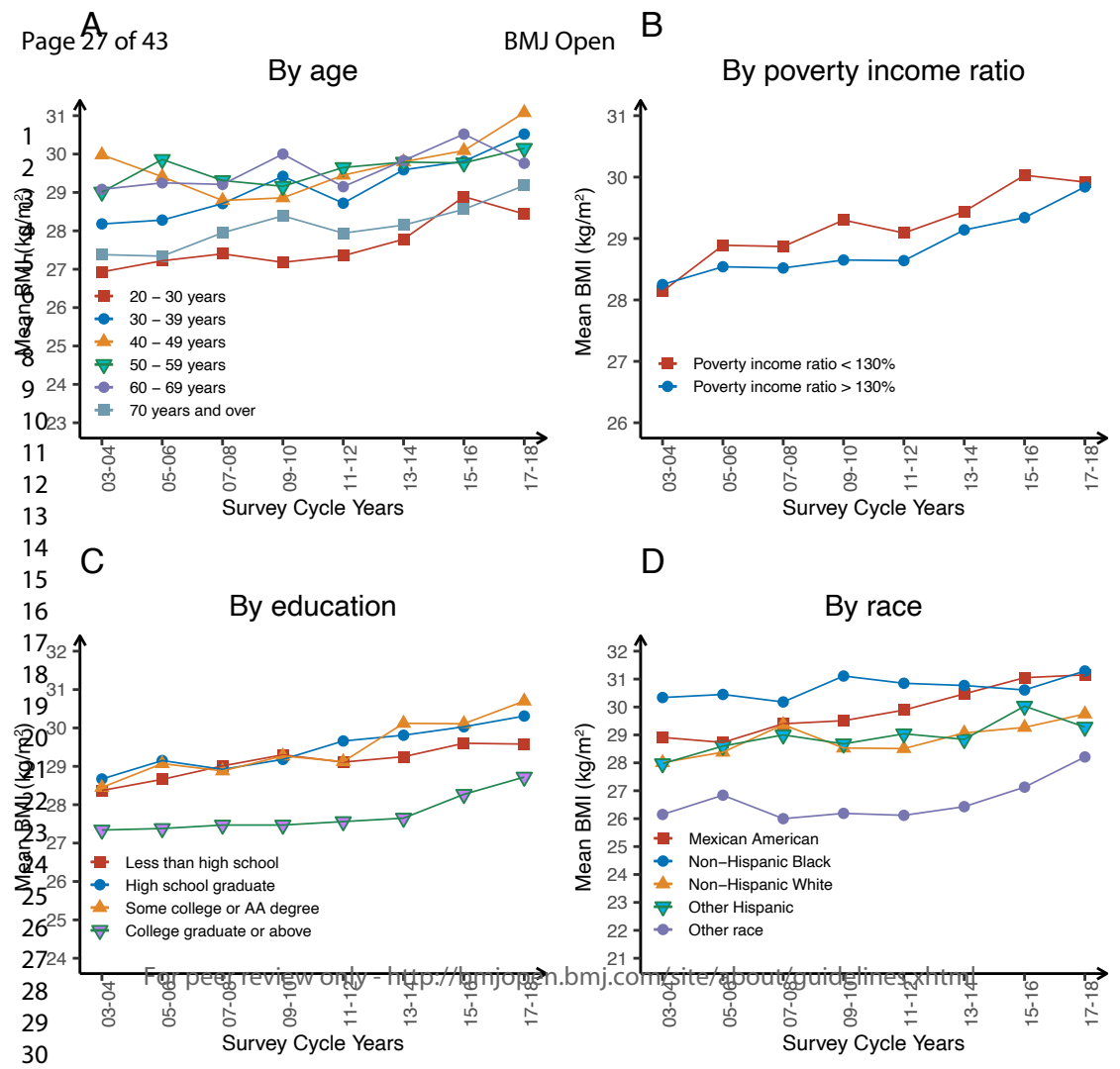

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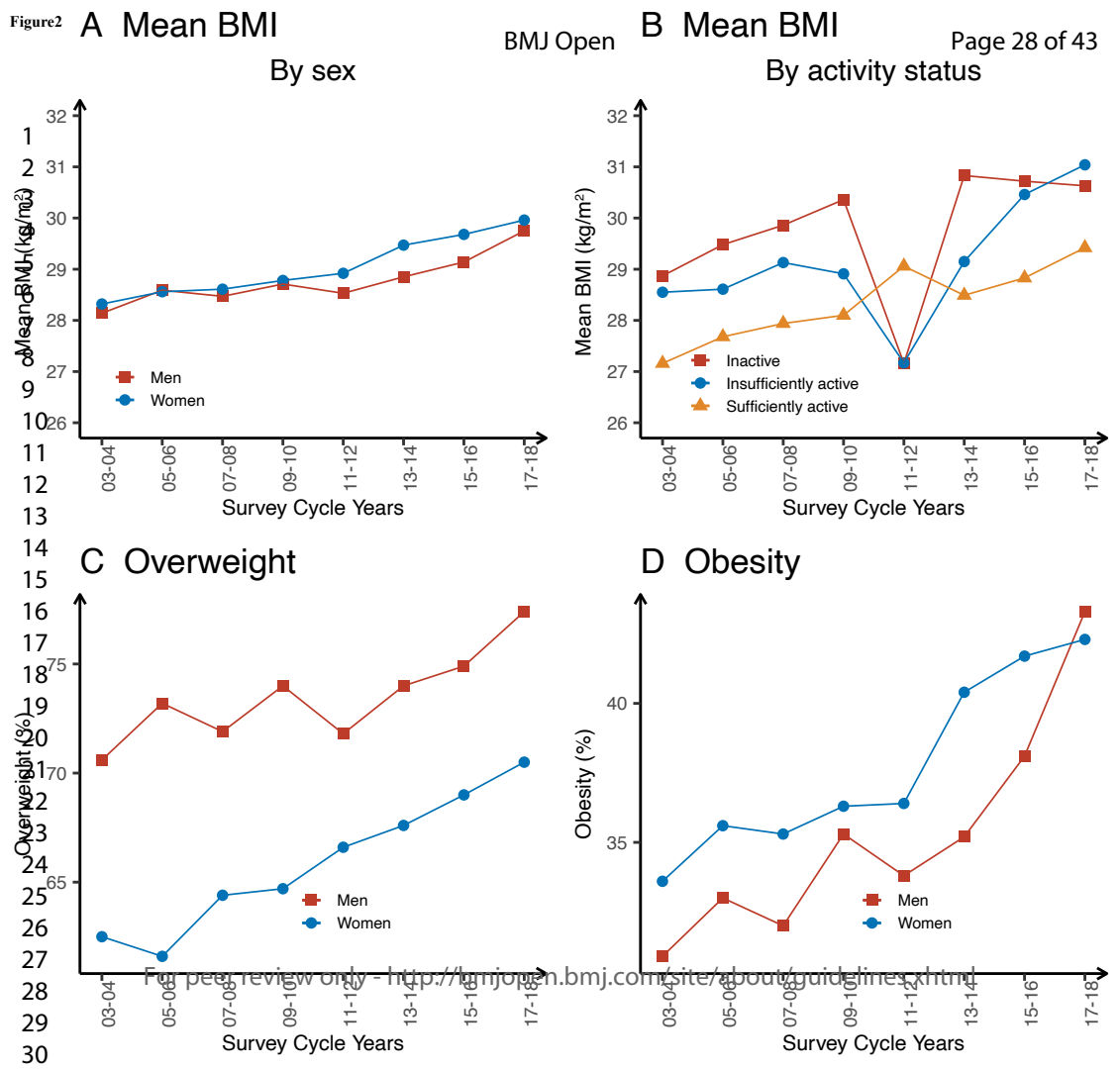

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Supplementary material

TITLE: Trends in body mass index, overweight and obesity among adults in the United States, NHANES 2003 to 2018: a repeat cross-sectional survey

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For the annual change in mean BMI and annual relative change in the prevalence of obesity and overweight, the calculation formulas were as follows:

- Annual change in mean BMI (kg/m^2):

$$\text{annual change} == \frac{(\text{level}_{t2} - \text{level}_{t1})}{(t2 - t1)}$$

- Annual relative change in the prevalence of overweight and obesity:

$$\text{annual change} = \left(\frac{\text{level}_{t2}}{\text{level}_{t1}}\right)^{\frac{1}{t2-t1}} - 1$$

Table S1. Characteristics of participants according to BMI groups*

Characteristic	Total (n=42,266)	BMI, kg/m² †			p-value
		< 25 (n=12,522)	25.0-29.9 (n=14,046)	⩾ 30 (n=1,5698)	
Age, years	47.11 ± 0.20	44.29 ± 0.30	48.78± 0.24	47.99 ± 0.22	< 0.001
Age, years, n (%)					<0.001
20 - 30	8,033 (20.54)	3,396 (29.24)	2,180 (16.73)	2,457 (16.63)	
30 - 39	7,175 (18.37)	2,104 (18.37)	2,334 (18.12)	2,737 (18.61)	
40 - 49	7,035 (19.43)	1,772 (16.64)	2,408 (20.50)	2,855 (20.84)	
50 - 59	6,714 (18.11)	1,675 (15.60)	2,224 (18.28)	2,815 (20.08)	
60 - 69	6,629 (12.76)	1,521 (9.62)	2,340 (13.84)	2,768 (14.43)	
≥ 70	6,680 (10.78)	2,054 (10.54)	2,560 (12.53)	2,066 (9.41)	
Sex, n (%)					< 0.001
Male, n (%)	20,408 (47.97)	5,784 (41.87)	7,773 (55.66)	6,851 (46.17)	
Female, n (%)	21,858 (52.03)	6,738 (58.13)	6,273 (44.34)	8,847 (53.83)	
Race, n (%)					< 0.001
Mexican American	6,805 (8.38)	1,355 (5.61)	2,581 (9.35)	2,869 (9.86)	
Other Hispanic	3,755 (5.33)	917 (4.51)	1,412 (6.04)	1,426 (5.38)	
Non-Hispanic White	18,120 (67.36)	5,735 (69.30)	6,070 (67.90)	6,315 (65.24)	
Non-Hispanic Black	9,094 (11.41)	2,268 (9.24)	2,624 (9.82)	4,202 (14.70)	
Other Race	4,492 (7.51)	2,247 (11.35)	1,359 (6.89)	886 (4.82)	
Education, n (%)					< 0.001
Less than high school	10,814 (16.4)	2,899 (15.19)	3,779 (16.79)	4,136 (16.95)	
High school graduate	9,787 (23.6)	2,747 (21.39)	3,200 (23.25)	3,840 (25.84)	
Some college or AA degree	12,266 (31.4)	3,409 (29.03)	3,860 (29.85)	4,997 (34.71)	
College graduate or above	9,345 (28.6)	3,441 (34.26)	3,194 (30.06)	2,710 (22.43)	
Poverty income ratio, n (%)					< 0.001
< 130%	12,129 (21.29)	3,588 (21.83)	3,802 (19.69)	4,739 (22.28)	
≥ 130%	26,450 (78.71)	7,863 (78.17)	8,944 (80.31)	9,643 (77.72)	
BMI, kg/m²	28.93 ±0.07	22.20 ± 0.02	27.44 ±0.02	35.98 ±0.07	
Total energy intake, Kcal/d	2,027.31±7.96	2051.4 ±12.7	2049.5 ± 12.8	1988.0 ± 11.1	< 0.001
Total energy intake, n (%)					< 0.001
Tertile1	9,991 (25.36)	2,614 (24.87)	3,245 (23.89)	4,132 (27.06)	
Tertile2	8,990 (27.08)	2,609 (26.89)	3,080 (28.30)	3,301 (26.16)	
Tertile3	15,644 (47.56)	4,673 (48.24)	5,180 (47.81)	5,791 (46.79)	
Physical activity, n (%)					< 0.001
Inactive	8,504 (18.09)	2,138 (14.52)	2,744 (16.99)	3,622 (22.15)	
Insufficiently active	6,649 (17.52)	1,995 (17.40)	2,232 (17.63)	2,422 (17.51)	
Sufficiently active	23,320 (64.39)	7,295 (68.09)	7,761 (65.38)	8,264 (60.34)	

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination

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Survey (2003-2018).

† Values are presented as mean ± SE for continuous variables and unweighted numbers (weighted %) for categorical variables.

Abbreviations: AA, Associate of Arts; BMI, body mass index

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Table S2. Mean BMI overtime among adults in the United States, 2003-2018 *

Characteristics	BMI (weighted mean ± SE), kg/m²								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Overall	28.93 ± 0.07	28.24 ± 0.15	28.57 ± 0.23	28.54 ± 0.16	28.75 ± 0.13	28.73 ± 0.21	29.17 ± 0.17	29.42 ± 0.25	29.86 ± 0.26
Age, years									
20 - 30	27.54 ± 0.14	26.93 ± 0.21	27.22 ± 0.34	27.40 ± 0.45	27.18 ± 0.30	27.35 ± 0.38†	27.78 ± 0.42†	28.89 ± 0.39‡	28.44 ± 0.55‡
30 - 39	29.16 ± 0.13	28.18 ± 0.37	28.28 ± 0.36	28.71 ± 0.28	29.42 ± 0.32	28.72 ± 0.33	29.59 ± 0.35†	29.81 ± 0.31‡	30.52 ± 0.48‡
40 - 49	29.53 ± 0.13	28.98 ± 0.28	29.41 ± 0.32	28.79 ± 0.27	28.86 ± 0.22	29.45 ± 0.35	29.80 ± 0.42	30.09 ± 0.52†	31.08 ± 0.36‡
50 - 59	29.61 ± 0.14	29.01 ± 0.41	29.86 ± 0.43†	29.31 ± 0.42	29.16 ± 0.24	29.65 ± 0.51	29.79 ± 0.31†	29.77 ± 0.40	30.15 ± 0.32‡
60 - 69	29.66 ± 0.13	29.08 ± 0.23	29.25 ± 0.29	29.21 ± 0.33	30.00 ± 0.29	29.15 ± 0.40	29.83 ± 0.32	30.52 ± 0.40†	29.76 ± 0.46
≥ 70	28.16 ± 0.10	27.38 ± 0.23	27.34 ± 0.25	27.95 ± 0.25†	28.39 ± 0.22‡	27.94 ± 0.31‡	28.15 ± 0.24‡	28.56 ± 0.35‡	29.18 ± 0.26‡
Sex									
Male	28.79 ± 0.08	28.14 ± 0.13	28.59 ± 0.25	28.47 ± 0.16	28.71 ± 0.21	28.53 ± 0.23	28.85 ± 0.15	29.14 ± 0.26‡	29.75 ± 0.27‡
Female	29.07 ± 0.09	28.32 ± 0.24	28.56 ± 0.28	28.61 ± 0.20	28.78 ± 0.14†	28.92 ± 0.23‡	29.47 ± 0.26‡	29.68 ± 0.29‡	29.96 ± 0.37‡
Race									
Mexican American	29.96 ± 0.13	28.91 ± 0.39	28.73 ± 0.22	29.40 ± 0.31	29.51 ± 0.27	29.89 ± 0.38	30.47 ± 0.24‡	31.05 ± 0.33‡	31.15 ± 0.35‡
Other Hispanic	29.05 ± 0.15	27.97 ± 0.64	28.60 ± 0.51	29.00 ± 0.41	28.68 ± 0.41	29.04 ± 0.31‡	28.84 ± 0.50	30.03 ± 0.40‡	29.28 ± 0.33‡
Non-Hispanic White	28.73 ± 0.09	28.01 ± 0.18	28.38 ± 0.25	28.37 ± 0.26	28.53 ± 0.16‡	28.51 ± 0.28‡	29.07 ± 0.19‡	29.27 ± 0.26‡	29.75 ± 0.35‡
Non-Hispanic Black	30.72 ± 0.11	30.34 ± 0.31	30.45 ± 0.28	30.18 ± 0.30	31.11 ± 0.35	30.85 ± 0.28	30.77± 0.31	30.61± 0.34	31.29 ± 0.29†
Other race	26.77 ± 0.16	26.15 ± 0.52	26.84 ± 0.65	26.00 ± 0.55	26.19 ± 0.39	26.12 ± 0.41	26.43 ± 0.36	27.13 ± 0.42	28.21 ± 0.39‡
Education									
Less than high school	29.09 ± 0.09	28.37 ± 0.32	28.66 ± 0.16	29.01 ± 0.25	29.30 ± 0.22‡	29.11 ± 0.28‡	29.25 ± 0.21‡	29.60 ± 0.29‡	29.58 ± 0.37‡
High school graduate	29.47 ± 0.10	28.67 ± 0.20	29.15 ± 0.27	28.92 ± 0.29	29.18 ± 0.20†	29.66 ± 0.37†	29.81 ± 0.33‡	30.03 ± 0.38‡	30.31 ± 0.18‡

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Some college or AA degree	29.51 ± 0.10	28.45 ± 0.22	29.07± 0.29	28.88 ± 0.25	29.27 ± 0.17†	29.12 ± 0.28†	30.12 ± 0.27‡	30.11 ± 0.33‡	30.70 ± 0.32‡
College graduate or above	27.78 ± 0.11	27.34 ± 0.33	27.38 ± 0.37	27.40 ± 0.28	27.47 ± 0.30	27.56 ± 0.34†	27.65 ± 0.20†	28.27 ± 0.26‡	28.72 ± 0.43‡
Poverty income ratio									
< 130%	28.14 ± 0.22	28.14 ± 0.22	28.89 ± 0.31†	28.87 ± 0.28†	29.30± 0.34‡	29.09± 0.21‡	29.44± 0.21‡	30.03 ± 0.32‡	29.92 ± 0.39‡
≥ 130%	28.25 ± 0.15	28.25 ± 0.15	28.54 ± 0.24	28.52 ± 0.16	28.65 ± 0.15†	28.64 ± 0.26‡	29.14 ± 0.23‡	29.34 ± 0.27‡	28.24 ± 0.15‡
Physical activity									
Inactive	28.53 ± 0.09	28.87 ± 0.72	29.48 ± 0.82	29.86 ± 0.21	30.36 ± 0.21	27.16 ± 0.35†	30.83 ± 0.30†	30.72± 0.33†	30.63 ± 0.39†
Insufficiently active	28.98 ± 0.12	28.55 ± 0.20	28.61 ± 0.28	29.13 ± 0.34	28.91 ± 0.21	27.17 ± 0.38‡	29.15 ± 0.32	30.46 ± 0.58‡	31.04 ± 0.42‡
Sufficiently active	28.53 ± 0.09	27.16 ± 0.23	27.68 ± 0.27	27.94 ± 0.20†	28.10± 0.18‡	29.06 ± 0.22‡	28.49 ± 0.17‡	28.83 ± 0.25‡	29.42 ± 0.29‡
Total energy intake									
Tetile 1	29.30 ± 0.11	28.51 ± 0.19	29.21 ± 0.30	28.66 ± 0.24	29.37 ± 0.25‡	29.04 ± 0.31†	29.58 ± 0.34‡	29.83 ± 0.33‡	29.91 ± 0.35‡
Tetile 2	28.95 ± 0.11	27.94 ± 0.22	28.78 ± 0.26‡	28.49 ± 0.27‡	28.81 ± 0.23‡	28.92 ± 0.23‡	29.25 ± 0.34‡	29.31 ± 0.34‡	29.98 ± 0.45‡
Tetile 3	28.97 ± 0.10	28.53 ± 0.29	28.37 ± 0.36	28.72 ± 0.19	28.52 ± 0.24	28.84 ± 0.34†	29.14 ± 0.22†	29.65 ± 0.23‡	29.96 ± 0.27‡

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003–2018). († $p < 0.05$; ‡ $p < 0.01$)

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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Table S3. Prevalence of obesity overtime among adults in the United States, 2003-2018 *

Characteristics	Prevalence (95CI),%								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Overall	36.7 (35.7, 37.6)	32.3 (29.9, 34.6)	34.4 (31.6, 37.2)	33.7 (31.5, 35.9)	35.8 (34.0, 37.7)	35.2 (32.4, 37.9)	37.9 (36.2, 39.6)	40.0 (37.0, 43.0)	42.8 (39.5, 46.1)
Age, years									
< 30	29.6 (27.9, 31.4)	26.1 (23.1, 29.0)	27.7 (22.7, 32.6)	27.4 (21.6, 33.2)	27.7 (24.0, 31.4)	29.0 (23.9, 34.1)	29.5 (25.8, 33.1)	31.7 (26.7, 36.7) ‡	37.5 (30.2, 44.8) ‡
30 - 39	37.1 (35.5 ,38.7)	32.5 (27.6, 37.5)	31.1 (26.6, 35.6)	35.5 (30.5, 39.7)	39.7 (35.4, 44.1) †	33.5 (30.2, 36.9)	39.9 (35.9, 43.9) †	40.5 (37.0, 44.1) †	44.3 (38.8, 49.9) ‡
40 - 49	39.3 (37.7, 40.9)	36.7 (34.2, 39.2)	39.0 (34.4, 43.6)	33.7 (29.4, 38.1)	36.2 (33.0, 39.5)	38.8 (33.4, 44.2)	41.1 (35.7, 46.5)	44.0 (38.1, 49.8) †	46.3 (41.7, 51.0) ‡
50 - 59	40.5 (38.6, 42.4)	35.9 (29.6, 42.1)	43.2 (38.6, 47.7)	38.1 (32.5, 43.6)	37.2 (33.8, 40.5)	39.5 (33.2, 45.9)	41.7 (37.1, 46.3)	42.7 (35.8, 49.6)	44.9 (40.7, 49.1) ‡
60 - 69	41.6 (39.6, 43.6)	35.7 (32.1, 39.3)	38.7 (34.1, 43.3)	38.6 (34.4, 42.8)	43.8 (39.7, 48.0) ‡	39.5 (34.5, 44.6) ‡	42.9 (38.9, 46.9) †	46.0 (40.3, 51.6) ‡	43.3 (35.3 ,51.4) †
≥ 70	32.2 (30.7, 33.6)	26.2 (22.4, 30.0)	25.8 (21.4, 30.2)	30.9 (27.0, 34.8) †	33.4 (30.0, 36.8) ‡	29.5 (26.4, 32.7) ‡	32.7 (28.4 ,37.0) ‡	35.5 (30.9, 40.1) ‡	40.3 (36.0, 44.6) ‡
Sex									
Men	35.3 (34.1, 36.6)	30.9 (28.4 ,33.4)	33.0 (28.9, 37.1)	32.0 (29.1, 34.8)	35.3 (31.9, 38.7) †	33.8 (31.2, 36.4)	35.2 (33.2, 37.2) ‡	38.1 (33.9, 42.3) ‡	43.3 (38.2, 48.4) ‡
Women	37.9 (36.8, 38.9)	33.6 (30.3, 36.8)	35.6 (33.0, 38.3)	35.3 (33.0, 37.6)	36.3 (34.5, 38.1) †	36.4 (33.0, 39.8) ‡	40.4, 37.9, 43.0) ‡	41.7 (38.7, 44.7) ‡	42.3 (38.6, 46.0) ‡
Race									
Mexican American	43.1 (41.5, 44.8)	36.3 (31.2, 41.4)	33.3 (31.6, 35.1)	39.2 (32.2, 46.2)	38.9 (36.4, 43.4)	45.2 (40.7, 49.7) ‡	46.7 (42.5, 51.0) ‡	49.0 (45.6, 52.4) ‡	51.6 (47.5, 55.8) ‡
Other Hispanic	37.0 (35.0, 39.1)	29.5 (19.2, 39.8)	34.2 (26.6, 41.9)	34.9 (30.3, 39.6)	34.7 (28.8, 40.6)	38.1 (32.7, 43.6) ‡	36.9 (31.2, 42.6) †	44.2 (38.4, 49.9) ‡	37.0 (42.7, 41.2) ‡
Non-Hispanic White	35.5 (34.4, 36.6)	31.0 (28.5, 33.4)	33.3 (30.2, 36.5)	32.6 (29.2, 36.0)	34.7 (32.4, 37.1) ‡	33.4 (29.9, 37.0) ‡	37.0 (35.0, 39.1) ‡	38.9 (35.7, 42.1) ‡	43.0 (38.2, 47.7) ‡
Non-Hispanic Black	47.1 (45.7, 48.5)	45.2 (40.9, 49.4)	45.4 (42.0, 48.8)	43.6 (39.6, 47.5)	49.9 (45.1, 54.7)	47.8 (44.3, 51.2)	47.9 (43.8, 52.1)	46.8 (42.5, 51.1)	49.8 (46.9, 52.7)
Other race	23.7 (21.4, 25.9)	19.0 (9.9, 28.0)	26.4 (17.6, 35.2)	19.4 (9.9, 29.0)	19.7 (15.4, 24.0)	18.8 (13.9, 23.8)	21.4 (16.7, 26.0)	28.0 (21.3, 36.7)	30.6 (25.5, 35.7) †
Education									
Less than high school	37.9 (36.7, 39.2)	34.3 (30.0, 38.5)	35.7 (33.3, 38.1)	37.6 (33.1, 42.0)	37.6 (34.9, 40.3) †	37.7 (35.1, 40.4) †	40.6 (37.5, 43.6)	40.3 (36.3, 43.7) ‡	41.4 (37.3, 45.6) †
High school graduate	40.0 (38.5, 41.4)	34.3 (30.5, 38.1)	38.9 (35.1, 42.6)	35.0 (31.6, 38.4)	38.3 (34.6, 42.0)	40.3 (35.3, 45.5) †	41.3 (37.0, 45.7) ‡	43.7 (38.6, 48.9) ‡	47.2 (43.2, 51.2) ‡

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Some college or AA degree	40.7 (39.4, 41.9)	33.9 (30.4, 37.4)	36.8 (32.9, 40.7)	37.5 (34.4, 40.6)	40.6 (38.3, 42.9)‡	38.0 (34.0, 41.9)†	42.9 (40.1, 45.7)‡	46.0 (42.2, 49.8)‡	47.7 (43.8, 51.5)‡
College graduate or above	28.8 (27.2, 30.4)	26.3 (22.0, 30.7)	26.2 (21.9, 30.5)	24.9 (20.9, 28.9)	27.5 (23.7, 31.4)	27.6 (22.5, 32.8)	28.7 (26.2, 31.3)†	31.5 (27.5, 35.4)‡	34.7 (29.1, 40.2)‡
Poverty income ratio									
< 130%	38.4 (37.2, 39.6)	32.3 (29.7, 34.6)	36.3 (33.1, 39.6)‡	35.9 (32.1, 39.7)†	38.4 (34.8, 41.9)‡	38.0 (35.5, 40.6)‡	39.4 (36.9, 41.8)‡	42.0 (38.1, 45.9)‡	43.8 (39.7, 47.9)‡
≥ 130%	36.4 (35.3, 37.4)	32.3 (29.6, 34.9)	34.3 (31.0, 37.6)	33.1 (30.9, 35.4)	35.7 (33.4, 37.9)†	34.3 (31.0, 37.6)†	37.6 (35.3, 40.0)‡	39.8 (36.3, 43.2)‡	43.1 (39.6, 46.7)‡
Physical activity									
Inactive	44.8 (43.4, 46.2)	38.0 (30.4, 45.6)	41.7 (29.5, 53.9)	42.6 (39.7, 45.4)	44.4 (42.4, 46,4)	26.2 (20.0, 32.3)†	48.5 (44.9, 52.1)†	48.0 (44.5, 51.5)†	46.7 (43.1, 50.4)†
Insufficiently active	36.4 (34.8, 38.0)	33.7 (30.6, 36.7)	34.0 (30.8, 37.3)	36.3 (31.1, 41.4)	37.3 (33.0, 41.6)	27.4 (22.0, 32.8)†	36.9 (33.6, 40.1)	44.5 (37.2, 51.8)‡	48.3 (41.7, 54.9)‡
Sufficiently active	34.3 (33.2,35.4)	24.8 (21.5, 28.2)	29.1 (24.9, 33.4)	30.0 (27.5, 32.5)†	32.3 (29.7, 34.9)‡	36.9 (34.2, 39.5)‡	33.7 (31.9, 35.5)‡	36.6 (33.4, 39.7)‡	40.6 (36.7, 44.6)‡
Total energy intake									
Tetile 1	39.9 (38.4,41.3)	34.5 (32.2, 36.8)	38.2 (34.8, 41.7)	36.1 (33.1, 39.0)	39.3 (36.1, 42.5)‡	38.5 (33.6, 43.4)	40.8 (36.2, 45.3)‡	43.4 (39.2, 47.6)‡	46.1 (41.4, 50.8)‡
Tetile 2	36.0 (34.5, 37.6)	30.1 (26.7, 33.4)	35.8 (31.7, 39.8)†	32.1 (28.5, 35.7)	36.1 (32.8, 39.4)†	34.7 (31.4, 38.1)‡	38.0 (33.4, 42.7)‡	37.9 (33.2, 42.7)‡	43.3 (37.1, 49.4)‡
Tetile 3	36.7 (35.5, 38.0)	33.9 (29.9, 37.8)	32.6 (28.4, 36.9)	34.8 (32.0, 37.6)	35.0 (31.6, 38.4)	35.4 (31.6, 39.3)†	37.5 (34.8, 40.2)†	41.3 (37.6, 45.1)‡	43.3 (39.4, 47.2)‡

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003–2018). († $p < 0.05$; ‡ $p < 0.01$)

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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Table S4. Prevalence of overweight overtime among adults in the United States, 2003-2018 *

Characteristics	Prevalence (95CI),%								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Overall	69.6 (68.7, 70.5)	66.3 (64.4, 68.3)	67.2 (64.6, 69.8)	68.0 (66.2, 69.8)	69.2 (66.6, 71.7)	69.1 (65.9, 72.3)	70.7 (69.0, 72.3)	71.8 (68.9, 74.8)	73.8 (71.1, 76.4)
Age, years									
20 - 30	56.6 (54.7, 58.5)	53.4 (49.1, 57.6)	56.4 (51.9, 60.8)	55.2 (51.1, 59.3)	56.7 (50.7, 62.7)	54.9 (47.4, 62.3)	56.6 (52.4, 60.9)	59.7 (55.3, 64.1)†	59.4 (53.2, 65.5)†
30 - 39	69.8 (68.1, 71.4)	63.0 (57.7, 68.4)	64.6 (59.1, 70.0)	69.3 (65.9, 72.8)	70.7 (67.0, 74.5)†	68.6 (64.4, 72.7)	72.3 (68.2, 76.3)‡	73.2 (69.5, 76.8)‡	76.2 (70.6, 81.8)‡
40 - 49	74.0 (72.4, 75.5)	73.9 (69.2, 78.6)	70.2 (66.2, 74.2)	71.4 (67.6, 75.3)	69.6 (66.4, 72.9)	75.9 (71.7, 80.1)	76.6 (73.0, 80.2)	73.9 (68.7, 79.0)	80.9 (75.5, 86.3)
50 - 59	74.0 (72.4, 75.6)	71.1 (66.7, 75.5)	75.5 (91.0, 79.9)	71.9 (66.7, 77.1)	74.3 (70.0, 78.5)	75.2 (70.6, 79.8)	74.6 (72.2, 77.0)	74.1 (69.6, 78.7)	74.8 (69.3, 80.4)
60 - 69	77.1 (75.4, 78.8)	76.7 (73.4, 80.1)	76.7 (71.7, 81.6)	75.5 (71.4, 79.6)	78.6 (74.7, 82.5)	74.4 (68.3, 80.6)	76.0 (72.5, 79.5)	80.1 (74.5, 85.7)	78.1 (73.6, 82.5)
≥ 70	70.2 (68.9, 71.4)	65.6 (61.0, 70.2)	63.9 (60.4, 67.4)	69.1 (65.8, 72.4)	71.0 (68.2, 73.8)†	67.4 (63.8, 70.9)†	70.8 (68.2, 73.4)†	73.8 (70.2, 77.4)‡	77.1 (73.5, 80.7)‡
Sex									
Male	73.5 (72.5, 75.6)	70.6 (68.0, 73.0)	73.2 (70.3, 76.2)	71.9 (70.1, 73.7)	74.0 (70.4, 77.6)	71.8 (68.6, 75.0)	74.0 (71.9, 76.1)†	74.9 (72.0, 77.8)†	77.4 (73.9, 80.9)‡
Female	66.0 (64.9, 67.1)	62.5 (59.9, 65.9)	61.6 (58.3, 64.8)	64.4 (61.7, 67.1)	64.7 (62.3, 67.1)	66.6 (63.0, 70.2)‡	67.6 (65.2, 70.0)‡	69.0 (65.4, 72.6)‡	70.5 (67.3, 73.6)‡
Race									
Mexican American	79.7 (78.1, 81.2)	73.8 (67.8, 79.8)	73.4 (69.8, 77.0)	77.3 (73.3, 81.2)	79.9 (76.5, 83.3)	78.6 (72.7, 84.5)	83.2 (80.1, 86.3)†	82.8 (78.9, 86.8)‡	85.3 (80.8, 89.9)‡
Other Hispanic	74.6 (72.9, 76.3)	68.4 (58.1, 78.7)	70.5 (62.3, 78.8)	74.8 (69.5, 80.1)	72.2 (69.4, 75.1)	75.2 (71.8, 78.7)	70.0 (64.7, 75.2)	78.5 (74.8, 82.2)	80.0 (76.0, 84.1)†
Non-Hispanic White	68.7 (67.7, 69.8)	65.2 (62.3, 68.0)	66.1 (62.8, 69.4)	67.2 (64.6, 69.9)	68.1 (65.0, 71.2)	68.7 (64.9, 72.5)†	70.6 (69.0, 72.2)†	71.5 (68.6, 74.3)†	72.2 (68.6, 75.8)‡
Non-Hispanic Black	75.5 (74.4, 76.6)	75.8 (72.8, 78.7)	75.5 (72.0, 79.1)	73.0 (70.6, 75.4)	76.4 (73.3, 79.5)	76.2 (73.0, 79.4)	75.5 (72.2, 78.7)	75.0 (71.8, 78.1)	76.4 (73.6, 79.1)
Other race	54.1 (51.9, 56.3)	50.4 (42.2,58.6)	51.0 (40.9, 61.0)	49.2 (41.9, 56.5)	53.0 (45.8, 60.1)	47.3 (43.5, 51.1)	50.1 (44.3, 56.0)	55.8 (50.6, 61.0)	66.5 (63.1, 70.0)‡
Education									
Less than high school	71.8 (70.4, 73.2)	66.9 (61.8, 72.0)	67.8 (64.6, 71.0)	71.3 (68.5, 74.1)	75.0 (70.9, 79.1)‡	71.7 (67.7, 75.7)	73.7 (70.9, 76.4)†	73.8 (69.1, 78.6)†	74.7 (71.4, 78.0)‡

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High school graduate	72.4 (71.2, 73.6)	69.5 (67.4, 71.6)	70.0 (66.3, 73.7)	69.9 (66.8, 72.9)	71.3 (68.3, 74.4)	73.1 (68.1, 78.1)	73.6 (70.5, 76.8) †	77.3 (73.4, 81.2) ‡	74.7 (71.6, 77.8) ‡
Some college or AA degree	71.9 (70.7, 73.1)	68.1 (64.8, 71.3)	70.1 (66.8, 73.4)	69.0 (66.2, 71.8)	70.2 (66.6, 73.8)	70.5 (65.8, 75.2)	74.4 (72.4, 76.5) ‡	74.7 (71.8, 77.6) ‡	76.9 (73.6, 80.1) ‡
College graduate or above	63.6 (62.0, 65.2)	60.0 (55.0, 65.0)	60.4 (55.2,65.7)	62.3 (58.1, 66.5) ‡	62.6 (57.3, 68.0)	63.8 (58.6, 69.0) ‡	63.0 (59.7, 66.2) ‡	64.5 (60.2, 68.9) ‡	69.5 (65.0, 74.0) ‡
Poverty income ratio									
< 130%	68.8 (67.4, 70.3)	62.6 (59.1, 66.1)	67.3 (63.1, 71.6) ‡	67.1 (63.9, 70.4) †	71.1 (66.3, 75.8) ‡	68.4 (64.2, 72.7) ‡	69.1 (65.9, 72.4) ‡	72.6 (68.1, 77.2) ‡	71.0 (67.1, 74.9) ‡
≥ 130%	69.9 (68.9, 70.9)	67.3 (64.8, 69.8)	67.2 (64.1, 70.4)	68.3 (66.5, 70.2)	68.8 (65.9, 71.6)	69.3 (65.6, 73.0)	71.3 (69.1, 73.6) †	71.6 (68.2, 75.0) †	74.9 (72.3, 77.4) ‡
Physical activity									
Inactive	75.6 (74.3, 76.9)	67.8 (59.4, 76.0)	74.2 (66.0, 82.6)	71.7 (69.5, 74.0)	76.3 (73.4, 79.2)	63.2 (56.5, 69.9)	78.4 (75.4, 81.5) †	77.6 (73.8, 81.4) †	78.3 (75.4, 81.2) †
Insufficiently active	69.7 (68.1, 71.3)	68.3 (66.1, 70.5)	68.2 (63.6, 72.7)	69.4 (65.9, 73.0)	68.1 (64.1, 72.1)	59.6 (53.1, 66.1) †	71.0 (66.0, 76.0)	76.0 (70.1, 81.8) †	81.1 (77.8, 84.4) ‡
Sufficiently active	67.9 (66.7, 69.1)	60.9 (56.1, 65.7)	62.0 (58.2, 65.7)	66.4 (63.9, 68.8)	66.7 (62.9, 70.4)	70.8 (67.6, 74.0) ‡	67.4 (65.4, 69.4) †	69.3 (66.3, 72.2) ‡	71.1 (67.8, 74.5) ‡
Total energy intake									
Tetile 1	70.9 (69.4, 72.3)	66.9 (63.7, 70.1)	68.1 (64.1, 72.0)	71.0 (67.4, 74.5)	69.7 (66.0, 73.3)	71.8 (66.7, 76.9)	72.9 (69.1, 76.7) ‡	73.9 (69.9, 77.9) ‡	71.7 (67.5, 75.8) ‡
Tetile 2	70.7 (69.3, 72.0)	65.0 (61.8, 68.2)	70.0 (66.3, 73.6) †	68.2 (64.2, 72.1)	70.6 (66.7, 74.6) †	71.5 (67.6, 75.3) †	73.2 (69.6, 76.8) ‡	71.1 (66.6, 75.7) †	75.4 (72.0, 78.9) ‡
Tetile 3	69.8 (68.7, 71.0)	68.4 (64.9, 71.9)	66.7 (63.0, 70.4)	68.7 (66.2, 71.3)	69.1 (65.0, 73.1)	68.2 (64.9, 71.4)	69.6 (66.9, 72.3)	73.1 (70.3, 75.8) †	75.0 (71.4, 78.5) †

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003–2018). († $p < 0.05$; ‡ $p < 0.01$)

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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Table S5. Change in mean BMI by sex among adults in the United States, 2003-2018

Years	Weighted mean BMI					
	Men		Women		Both	
	Adjusted β * (95%CI)	p-value	Adjusted β * (95%CI)	p-value	Adjusted β * (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	0.38 (-0.29,1.06)	0.259	0.44 (-0.47, 1.35)	0.338	0.38 (-0.23,0.99)	0.215
2007 - 2008	0.42 (-0.14,0.97)	0.139	0.52 (-0.10, 1.15)	0.102	0.48 (0.04,0.93)	0.035
2009 - 2010	0.72 (0.09,1.35)	0.025	0.64 (0.04, 1.23)	0.037	0.70 (0.26,1.15)	0.002
2011 - 2012	0.64 (0.04, 1.23)	0.035	1.50 (0.84, 2.16)	<0.001	1.08 (0.55, 1.61)	<0.001
2013 - 2014	0.73 (0.18, 1.28)	0.010	1.55 (0.78, 2.32)	<0.001	1.18 (0.66, 1.70)	<0.001
2015 - 2016	1.28 (0.62, 1.95)	<0.001	1.88 (1.15, 2.61)	<0.001	1.59 (1.03, 2.20)	<0.001
2017 - 2018	1.62 (1.00, 2.24)	<0.001	2.26 (1.30, 3.21)	<0.001	1.96 (1.34, 2.57)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: CI, confidence interval.

* Models adjusted for age, sex , race, education, family poverty income ratio, total energy intake and physical activity status.

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Table S6. Change in prevalence of obesity by sex among adults in the United States, 2003-2018

Years	Prevalence of obesity					
	Men		Women		Both	
	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	1.03 (0.96, 1.09)	0.402	1.04 (0.98, 1.09)	0.197	1.03 (0.99, 1.07)	0.184
2007 - 2008	1.03 (0.98, 1.08)	0.229	1.03 (0.99, 1.07)	0.193	1.03 (1.00, 1.06)	0.084
2009 - 2010	1.07 (1.02, 1.13)	0.008	1.04 (1.01, 1.08)	0.026	1.06 (1.03, 1.09)	<0.001
2011 - 2012	1.06 (1.03, 1.11)	0.028	1.08 (1.04, 1.13)	<0.001	1.07 (1.03, 1.11)	<0.001
2013 - 2014	1.06 (1.01, 1.11)	0.011	1.08 (1.05, 1.14)	<0.001	1.08 (1.04, 1.11)	<0.001
2015 - 2016	1.11 (1.04, 1.18)	<0.001	1.12 (1.07, 1.17)	<0.001	1.11 (1.07, 1.16)	<0.001
2017 - 2018	1.17 (1.09, 1.24)	<0.001	1.14 (1.08, 1.21)	<0.001	1.15 (1.10, 1.21)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: CI, confidence interval; OR, odds ratio.

Crude model: we did not adjust other covariants.

* Models adjusted for age, sex , race, education, family poverty income ratio, total energy intake and physical activity status.

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Table S7. Change in prevalence of overweight by sex among adults in the United States, 2003-2018

Years	Prevalence of overweight					
	Men		Women		Both	
	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	1.01 (0.96, 1.06)	0.580	1.01 (0.95, 1.08)	0.690	1.01 (0.97, 1.05)	0.598
2007 - 2008	1.00 (0.96, 1.05)	0.868	1.03 (0.98, 1.08)	0.206	1.02 (0.98, 1.05)	0.281
2009 - 2010	1.02 (0.97, 1.08)	0.406	1.03 (0.98, 1.08)	0.248	1.03 (0.99, 1.07)	0.178
2011 - 2012	1.01 (0.96, 1.06)	0.819	1.08 (1.03, 1.14)	0.002	1.05 (1.00, 1.09)	0.034
2013 - 2014	1.02 (0.98, 1.07)	0.370	1.07 (1.02, 1.12)	0.010	1.05 (1.01, 1.08)	0.012
2015 - 2016	1.03 (0.98, 1.08)	0.305	1.09 (1.04, 1.15)	0.001	1.06 (1.02,1.10)	0.005
2017 - 2018	1.05 (1.00, 1.11)	0.050	1.11 (1.05, 1.17)	<0.001	1.08 (1.04, 1.13)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: CI, confidence interval; OR, odds ratio.

* Models adjusted for age, sex , race, education, family poverty income ratio, total energy intake and physical activity status.

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Table S8. Characteristics of participants according to tertiles of daily total energy intake*

Characteristic	Total (n=34,625)	Daily total energy intake (Kcal/d) †			*P*-value
		Tertile1 (n=9,991)	Tertile2 (n=8,990)	Tertile3 (n=1,5644)	
Age, years	48.81 ± 0.48	49.57 ± 0.28	48.23± 0.28	46.38 ± 0.25	< 0.001
Sex, n (%)					< 0.001
Male, n (%)	16,457 (47.20)	3,159 (27.81)	4,442 (48.79)	8,856 (56.63)	
Female, n (%)	18,168 (52.80)	6,832 (72.19)	4,548 (51.21)	6,788 (43.37)	
Race, n (%)					< 0.001
Mexican American	5,430 (7.85)	1,670 (8.43)	1,383 (7.43)	2,377 (7.78)	
Other Hispanic	2,973 (5.02)	1,049 (6.46)	698 (4.33)	1,226 (4.65)	
Non-Hispanic White	15,635 (69.51)	3,905 (64.17)	4,353 (72.29)	7,377 (70.77)	
Non-Hispanic Black	7,384 (10.97)	2,465 (13.87)	1,759 (9.64)	3,160 (10.19)	
Other Race	3,203 (6.64)	902.00 (7.06)	797.00 (6.31)	1,504 (6.60)	
Education, n (%)					< 0.001
Less than high school	8,224 (14.99)	3,085 (19.78)	1,912(13.29)	3,227 (13.39)	
High school graduate	8,042 (23.55)	2,397 (25.76)	2,051 (22.95)	3,594 (22.71)	
Some college or AA degree	10,281 (31.61)	2,727 (29.98)	2,748 (32.51)	4,806 (31.98)	
College graduate or above	8,049 (29.80)	1,773 (24.41)	2,272 (31.20)	4,004 (31.88)	
Poverty income ratio, n (%)					< 0.001
< 130%	9,588 (19.89)	3,157(24.23)	2,335 (18.50)	4,096 (18.41)	
≥ 130%	22,370 (80.11)	5,931(75.77)	5,972 (81.50)	10,467 (81.59)	
BMI, kg/m^2	29.05 ±0.08	29.30±0.11	28.95 ±0.11	28.97±0.10	
BMI, kg/m^2 (group)					< 0.001
< 25	9,896 (30.04)	2,614 (29.47)	2,609 (29.83)	4,673 (30.47)	
25 - 30	11,505 (32.91)	3,245 (31.00)	3,080 (34.39)	5,180 (33.09)	
≥ 30	13,224 (37.04)	4,132 (39.53)	3,301 (35.78)	5,791 (36.44)	
Overweight					0.3
No	9,788 (29.68)	2,583 (29.14)	2,576 (29.33)	4,629 (30.16)	
Yes	24,837 (70.32)	7,408 (70.86)	6,414 (70.67)	11,015 (69.84)	
Obesity					< 0.001
No	21,294 (62.65)	5,829 (60.14)	5,660 (63.95)	9,805 (63.25)	
Yes	13,331 (37.35)	4,162 (39.86)	3,330 (36.05)	5,839 (36.75)	
Physical activity, n (%)					< 0.001
Inactive	6,677 (17.45)	2,329 (21.39)	1,681 (16.85)	2,667 (15.71)	
Insufficiently active	5,548 (17.92)	1,540 (16.56)	1,499 (18.54)	2,509 (18.29)	
Sufficiently active	19,207 (64.63)	5,127 (62.05)	5,007 (64.61)	9,073 (66.00)	

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination

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Survey (2003-2018).

† Values are presented as mean ± SE for continuous variables and unweighted numbers (weighted %) for categorical variables.

Abbreviations: AA, Associate of Arts; BMI, body mass index

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STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2,3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6,7*
Bias	9	Describe any efforts to address potential sources of bias	6,7
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	7,8
		(*c*) Explain how missing data were addressed	7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	7,8

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		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8,9
		(b) Indicate number of participants with missing data for each variable of interest	8,9
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	8,9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9,10,11
		(*b*) Report category boundaries when continuous variables were categorized	9,10,11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13,14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14,15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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BMJ Open

Trends in body mass index, overweight and obesity among adults in the United States, the NHANES from 2003 through 2018: a repeat cross-sectional survey

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Trends in body mass index, overweight and obesity among adults in the United States, the NHANES from 2003 through 2018: a repeat cross-sectional survey

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Abstract

Objectives: To analyse detailed trends in adult obesity from 2003 through 2018 in the United States (US), and provide the latest national estimates of adult obesity in 2017-2018.

Design, Setting, and Participants: Analysis of data, including measured height and weight, obtained from 42,266 adults aged ≥ 20 years from the National Health and Nutrition Examination Survey (NHANES), a cross-sectional, nationally representative sample of the US population.

Exposure: Survey period.

Primary Outcome Measures: The mean body mass index (BMI) and prevalence of overweight and obesity.

Results: In 2017-2018, the prevalence of overweight (including obesity, BMI ≥ 25 kg/m^2) and obesity (BMI ≥ 30 kg/m^2) was 73.8% (95% CI: 71.1%-76.4%) and 42.8% (95% CI: 39.5%-46.1%), respectively. From 2003 through 2018, a significant increase in the prevalence of overweight (including obesity, overall adjusted OR for 2017-2018 vs. 2003-2004, 1.08 [95% CI: 1.04-1.13]) and obesity (overall adjusted OR for 2017-2018 vs. 2003-2004, 1.15 [95% CI: 1.10-1.21]) was found among American adults. However, annual changes in mean BMI and the prevalence of overweight and obesity did not differ significantly before and after 2009-2010. The prevalence of overweight and obesity varied significantly by age, sex, race, education, daily total energy intake, economic conditions, and physical activity status (all $p < 0.05$).

Conclusions: Although the prevalence of adult obesity continues to rise, there have been no significant changes in the annual growth of adult obesity prevalence between 2003-2004 and 2017-2018. In 2017-2018, the prevalence of obesity was 42.8%, which equates to 76 million American adults at risk for serious and costly chronic conditions. The prevalence of obesity was higher among older adults (aged

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60-69 years), females, non-Hispanic Blacks, and those who did not graduate college, were physically inactive, reported lower daily total energy intake, and had poor economic status.

Keywords: American adults; body mass index; overweight/obesity; trends; NHANES

Strengths and limitations of this study

1. Our present study used a larger sample size as well as a longer time span than the previous studies.

2. Although NHANES is designed to provide nationally representative estimates, it is a repeated cross-sectional survey, which precludes within-individual change in BMI or obesity.

3. Our study assessed annual changes in BMI and obesity, and the potential effects of the 2008–2009 global financial crisis among US adults.

4. Obesity was defined mainly based on measurements of BMI, which does not measure body fat directly.

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1. Introduction

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Obesity is one of the most common risk factors for chronic diseases such as diabetes mellitus, cardiovascular diseases, renal damage, and cancers, which affected 670 million adults globally in 2016[1-7]. In the United States (US), the obesity rate has been on the rise since the 1980s [8]. By 2030, obesity is expected to reach a prevalence of 48.9% among American adults [9].

Some studies have reported trends in obesity prevalence among American adults using data from National Health and Nutrition Examination Survey (NHANES) [8, 10-19]. Between 1976-1980 and 1988-1994, the prevalence of obesity among American adults increased from 14.5% to 22.5% [10]. The prevalence of obesity increased from 22.9% to 30.5% from 1988-1994 through 1999-2000, maintaining similar growth rates of approximately 8% [11]. Over the period from 1999-2000 to 2017-2018, there was a larger increase in the prevalence of obesity among males (from 27.5% to 43.0%) than seen previously and a similar growth in the prevalence among females (from 33.4% to 41.9%) [14]. The majority of previous studies have focused on differences in the prevalence of obesity by age, sex, and race. Differences in the prevalence of obesity by other covariates such as educational level, economic status, daily total energy intake, and physical activity status have been scarcely studied. The effects of the 2008–2009 global financial crisis on economic status, physical activity status, and daily total energy intake are still unknown. How changes in economic status, physical activity status, and daily total energy intake may impact the prevalence of overweight and obesity is less well understood.

In this study, our primary aim was to provide the latest national estimates of adult obesity and evaluate trends in mean body mass index (BMI) and adult obesity from 2003 through 2018. The secondary aims of our study were as follows: (1) To explore the changes in mean BMI and adult obesity before and after 2009-2010. (i.e., before and after the 2008–2009 global financial crisis taken place); and (2) To assess how these trends might vary by age, sex, race, educational level, economic

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status, daily total energy intake, and physical activity status.

2. Materials and methods

2.1 Database and participants

The NHANES is a nationally representative sample of the US population, which collects data from survey participants through household interviews, standardized physical examinations, and laboratory tests in mobile examination centres [20]. The survey is unique in that it combines data from interviews and physical examinations. The NHANES released data every 2 years to ensure an adequate sample size for analyses and to protect confidentiality. The survey examines a nationally representative sample of approximately 5,000 people each year. The NHANES interview includes demographic, socioeconomic, dietary, and health-related questions. The examination component consists of medical, dental, and physiological measurements, as well as laboratory tests administered by highly trained medical personnel. Detailed information on the NHANES procedures is available in the literature [21].

The present study used NHANES data from adults aged ≥ 20 years (N = 44,790) collected from 8 survey cycles from 2003 through 2018. Among the 44,790 participants (21,668 males and 23,122 females), 42,266 had complete data on BMI, and were included in the final analysis.

2.2 Data collection

Information about anthropometric measurements (including height and weight) and BMI was obtained from examination data. Information about age, sex, race, education, and poverty income ratio (PIR) was obtained from demographic data. Data on total energy intake were obtained from the total nutrient intake file from the second-day dietary interview, which contains a summary of the individual's nutrition from all foods and beverages provided on the dietary recall. Total energy intake was categorized into tertiles. PIR was a ratio of family income to the poverty threshold, which was

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calculated by dividing family income by the poverty guidelines for the year the survey was completed. PIR was categorized into two groups: <130% and ≥130%. This classification of PIR has been used in a previous study [22]. Data on physical activity were obtained from the physical activity questionnaire. Based on the 2018 Physical Activity Guidelines for Americans, respondents who engaged in moderate-intensity aerobic activity for 150 min/week, vigorous-intensity aerobic activity for 75 min/week, or an equivalent combination of both (1 min of vigorous-intensity physical activity is equivalent to 2 min of moderate-intensity physical activity) were defined as meeting the guidelines [23]. In our analysis, physical activity was categorized into three levels: sufficiently active, insufficiently active, and inactive. Sufficiently active was defined as moderate-intensity aerobic activity for 150 min/week, vigorous-intensity aerobic activity for 75 min/week, or an equivalent combination of both. Insufficiently active was defined as some aerobic activity for 10-149 min/week, but not enough to meet the guidelines. Inactive was defined as some physical activity (< 10 min/week) or no reported physical activity [23]. This classification of physical activity has been used in previous studies [24].

2.3 Statistical analysis

According to the World Health Organization (WHO) classification, we defined overweight, including obesity, as BMI ≥ 25 kg/m^2 and obesity as ≥ 30 kg/m^2. Overall, the mean BMI and prevalence of overweight and obesity in each survey cycle were calculated by incorporating sample weights and adjusting for clusters and strata of the complex sample design of the NHANES. Individuals with missing demographic information on height or weight measurements were excluded from the analyses.

In Table 1, continuous variables are presented as weighted means and standard errors, while categorical variables are presented as unweighted counts and weighted proportions. Comparisons

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between survey cycles were made using the Wald test (categorical variables) or Kruskal–Wallis rank-sum test (skewed distribution).

We used survey-weighted generalized linear regression models to evaluate the trends in BMI and the prevalence of overweight and obesity by survey period. Multivariate survey-weighted generalized linear regression models were adjusted for age, sex, race, education, PIR, total energy intake, and physical activity status. A p value for the trends was obtained by entering the median value of each category of BMI, the prevalence of overweight and obesity as a continuous variable, and rerunning the corresponding survey-weighted generalized linear regression models.

We used a previously described method to compare trends in mean BMI and prevalence of overweight and obesity before and after 2009-2010 to explore the potential impact of the 2008–2009 global financial crisis [25]. We calculated annual mean BMI changes as the absolute value of the difference in mean BMI between the start and end years divided by the total number of years covered. We also calculated the annual relative changes in overweight and obesity prevalence as the absolute value of the difference in prevalence between the start and end years divided by the prevalence in the start year annualized by accounting for compounding. Welch's t tests were used to compare trends in mean BMI and prevalence of overweight and obesity before and after 2009-2010.

All simulations and analyses were performed using R software (R Foundation for Statistical Computing, Vienna, Austria, Version 3.6.3) and the "survey" package (e.g., svymean and svyglm), which considers sampling weights (16-year exam weight), clustering, and stratification of the complex survey design.[26] A two-sided p value <0.05 was considered to be statistically significant.

2.4 Ethics statement

Approval was obtained from the National Center for Health Statistics (NCHS) Research Ethics

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Review Board, and all participants provided written informed consent. Therefore, there was no need for any ethical consent in this study.

2.5 Patient and public involvement

The public was not involved in the design, conduct, reporting, or dissemination plans of our study.

3. Results

The demographic characteristics of all participants according to the 8 survey cycles are listed in Table 1. In total, 42,266 participants (20,408 males and 21,858 females) were included in our final analysis. The weighted mean (SE) age of the population was 47.11 (0.20) years, 47.97% of the population were male, and the weighted mean (SE) BMI was 28.93 (0.07) kg/m^2. Approximately two-thirds (67.36%) were non-Hispanic White, 11.41% were non-Hispanic Black, 8.38% were Mexican American, 5.33% were Hispanic and 7.51% were categorized as "other race". More than 80% had a minimum of a high school education and approximately 80% reported good economic status (PIR ≥ 130%). The average (SE) daily total energy intake was 2027.31 (7.96) kcal. Approximately 65% reported meeting physical activity guidelines. The prevalence of overweight and obesity increased over time, whereas the inverse was true for normal weight (p = 0.002). The prevalence of overweight and obesity varied significantly by age, sex, race, education, daily total energy intake, economic conditions, and physical activity status(Table S1).

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Table 1. Baseline characteristics of participants. *

Characteristics	National Health and Nutrition Examination Survey cycles †								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Age, years	47.11 ± 0.20	46.02 ± 0.52	46.42 ± 0.74	46.55 ± 0.44	46.92 ± 0.49	47.21 ± 0.82	47.45 ± 0.38	47.92 ± 0.58	48.14 ± 0.53
Age, years (group)									
20 - 30	8,033 (20.5)	940 (21.0)	1,101 (20.5)	928 (20.5)	1,134 (21.1)	1,043 (20.6)	1,025 (20.6)	1,016 (20.2)	846 (19.7)
30 - 39	7,175 (18.4)	759 (20.3)	823 (19.8)	997 (19.1)	1,010 (18.1)	916 (17.5)	951 (17.4)	921 (17.4)	798 (19.0)
40 - 49	7,035 (19.4)	742 (21.6)	782 (21.2)	920 (21.2)	1,063 (19.8)	869 (19.4)	991 (18.9)	896 (17.7)	772 (16.3)
50 - 59	6,714 (18.1)	596 (16.6)	622 (16.9)	902 (17.8)	956 (18.2)	877 (18.9)	914 (18.1)	917 (18.8)	930 (19.3)
60 - 69	6,629 (12.8)	695 (10.2)	631 (11.0)	894 (11.0)	876 (12.0)	820 (13.5)	866 (14.1)	863 (14.5)	984 (15.1)
≥ 70	6,680 (10.8)	915 (10.5)	721 (10.3)	966 (10.5)	955 (10.8)	712 (10.1)	773 (11.0)	793 (11.4)	845 (11.6)
Sex, n (%)									
Male, n (%)	20,408 (48.0)	2,237 (48.1)	2,237 (48.2)	2,746 (48.0)	2,889 (48.1)	2,585 (48.1)	2,638 (48.0)	2,638 (47.6)	2,493 (47.7)
Female, n (%)	21,858 (52.0)	2,410 (51.9)	2,443 (51.8)	2.861 (52.0)	3,105 (51.9)	4,652 (51.9)	2,882 (52.0)	2,882 (52.4)	2,682 (52.3)
Race									
Mexican American	6,805 (8.4)	931 (8.0)	944 (8.0)	967(8.3)	1,096 (8.6)	509 (7.7)	737 (9.1)	936 (8.8)	685 (8.7)
Other Hispanic	3,755 (5.3)	139 (3.5)	148 (3.4)	629 (4.9)	610 (5.0)	538 (6.5)	488 (5.6)	720 (6.4)	483 (6.9)
Non-Hispanic White	18,120 (67.4)	2,464 (72.0)	2,338 (71.9)	2,625 (69.6)	2,865 (67.9)	1,917 (66.5)	2,366 (65.9)	1,767 (64.0)	1,778 (62.4)
Non-Hispanic Black	9,094 (11.4)	910 (11.2)	1,064 (11.4)	1,155 (11.2)	1,087 (11.4)	1,382 (11.5)	1,135 (11.5)	1,142 (11.4)	1,219 (11.5)
Other Race	4,492 (7.5)	203 (5.4)	186 (5.2)	231 (6.1)	336 (7.2)	891 (7.7)	794 (7.9)	841 (9.4)	1,010 (10.5)
Education, n (%)									
Less than high school	10,814 (16.4)	1,362 (18.1)	1,290 (17.4)	1,728 (20.3)	1,710 (18.9)	1,235 (16.4)	1,191 (15.2)	1,277 (14.3)	1,021 (11.0)
High school graduate	9,787 (23.6)	1,167 (27.1)	1,119 (25.0)	1,392 (25.4)	1,376 (22.9)	1,098 (19.8)	1,232 (21.6)	1,172 (20.8)	1,231 (27.0)

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Some college or AA degree	12,266 (31.4)	1,263 (31.5)	1,334 (31.3)	1,440 (29.0)	1,679 (30.3)	1,576 (32.4)	1,704 (32.9)	1,602 (32.5)	1,668 (30.8)
College graduate or above	9,345 (28.6)	847 (23.2)	931 (26.1)	1,041 (25.3)	1,216 (27.7)	1,324 (31.3)	1,389 (30.3)	1,352 (32.4)	1,245 (31.1)
Poverty income ratio, n (%)									
< 130%	12,129 (21.3)	1,264 (20.5)	1,167 (17.1)	1,552 (20.4)	1,817 (21.7)	1,724 (24.6)	1,762 (24.7)	1,568 (20.9)	1,275 (20.1)
≥ 130%	26,450 (78.7)	3,119 (79.5)	3,294 (82.9)	3,536 (79.6)	3,592 (78.3)	3,078 (75.4)	3,335 (75.3)	3,280 (79.1)	3,216 (79.9)
BMI, kg/m^2	28.93 ± 0.07	28.24 ± 0.15	28.57 ± 0.23	28.54 ± 0.16	28.75 ± 0.13	28.73 ± 0.21	29.17 ± 0.17	29.42 ± 0.25	29.86 ± 0.26
BMI, kg/m^2 (group)									
< 25	12,522 (30.7)	1,480 (33.7)	1,432 (32.9)	1,628 (32.0)	1,684 (30.9)	1,714 (31.7)	1,700 (30.0)	1,517 (28.7)	1,367 (26.9)
25 - 30	14,046 (32.9)	1,632 (34.1)	1,608 (32.9)	1,934 (34.3)	2,030 (33.4)	1,677 (33.8)	1,767 (32.6)	1,731 (31.9)	1,667 (30.8)
≥ 30	15,698 (36.4)	1,535 (32.2)	1,640 (34.2)	2,045 (33.7)	2,280 (35.8)	1,846 (34.6)	2,053 (37.4)	2,158 (39.4)	2,141 (42.3)
Total energy intake, Kcal/d	2,027.31±7.96	2,113.90 ± 13.81	2,051.01 ± 25.07	2016.62 ± 20.87	2061.43±27.10	2014.61 ± 18.59	2017.22 ± 23.24	1970.20 ± 23.28	1980.34 ± 23.18
Physical activity, n (%)									
Inactive	8,504 (18.1)	150 (5.6)	142 (4.4)	1,656 (23.1)	1,711 (23.7)	355 (6.8)	1,562 (26.3)	1,565 (23.0)	1,363 (21.2)
Insufficiently active	6,649 (17.5)	1,380 (50.2)	1,403 (47.5)	734 (13.0)	817 (13.7)	536 (10.3)	568 (9.7)	567 (9.9)	644 (11.3)
Sufficiently active	23,320 (64.4)	1,156 (44.2)	1,303 (48.2)	3,217 (63.8)	3,466 (62.7)	4,346 (82.9)	3,390 (64.0)	3,274 (67.1)	3,168 (67.5)

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003-2018).

† Values are presented as mean ± SE for continuous variables and unweighted numbers (weighted %) for categorical variables.

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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The mean (SE) BMI levels increased from 28.24 (0.07) kg/m^2 in 2003-2004 to 29.86 (0.26) kg/m^2 in 2017-2018 (Table S2). In 2017-2018, the obesity prevalence was 42.8% (95% CI: 39.5%-46.1%), increasing more than 10% from 32.3% in 2003-2004 (95% CI: 29.9%-34.6%) (Table S3). Consistent with the increase in mean BMI and obesity prevalence, we found that the prevalence of overweight (including obesity) increased from 66.3% (95% CI: 64.4%-68.3%) in 2003-2004 to 73.8% (95% CI: 71.1%-76.4%) in 2017-2018 (Table S4). We used survey-weighted generalized linear regression models to evaluate the trends in BMI and prevalence of overweight and obesity by survey period (Table 2). Compared with 2003-2004, the mean (SE) BMI increased by 1.96 kg/m^2 (95% CI: 1.34-2.57, $p < .001$) in 2017-2018 after adjusting for age, sex, race, education, PIR, and physical activity status (Table 2, Table S5). The findings were similar for the prevalence of overweight and obesity. Compared with 2003-2004, the adjusted odds ratios for the prevalence of overweight (including obesity) and obesity were 1.08 (95% CI: 1.04-1.13, $p < .001$) and 1.15 (95% CI 1.10-1.21, $p < .001$), respectively (Table 2, Table S6, Table S7). However, we found no significant effect of the survey cycle on the prevalence of overweight among males after adjusting for potential confounding variables (adjusted odds ratio 1.05, 95% CI: 1.00-1.11, $p = 0.050$) (Table S7).

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Table 2. Change in BMI, overweight and obesity over time among adults in the United States, 2003-2018

Years	Mean BMI		Prevalence of overweight		Prevalence of obesity	
	Adjusted β * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	0.38 (-0.23,0.99)	0.215	1.01 (0.97, 1.05)	0.598	1.03 (0.99, 1.07)	0.184
2007 - 2008	0.48 (0.04,0.93)	0.035	1.02 (0.98, 1.05)	0.281	1.03 (1.00, 1.06)	0.084
2009 - 2010	0.70 (0.26,1.15)	0.002	1.03 (0.99, 1.07)	0.178	1.06 (1.03, 1.09)	<0.001
2011 - 2012	1.08 (0.55, 1.61)	<0.001	1.05 (1.00, 1.09)	0.034	1.07 (1.03, 1.11)	<0.001
2013 - 2014	1.18 (0.66, 1.70)	<0.001	1.05 (1.01, 1.08)	0.012	1.08 (1.04, 1.11)	<0.001
2015 - 2016	1.59 (1.03, 2.20)	<0.001	1.06 (1.02,1.10)	0.005	1.11 (1.07, 1.16)	<0.001
2017 - 2018	1.96 (1.34, 2.57)	<0.001	1.08 (1.04, 1.13)	<0.001	1.15 (1.10, 1.21)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio.

* Models adjusted for age, sex, race, education, family poverty income ratio, daily total energy intake and physical activity status.

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Table 3 shows the annual change in mean BMI as well as overweight and obesity prevalence from 2003-2004 to 2009-2010 and from 2011-2012 to 2017-2018. The increase in mean BMI was somewhat larger after 2009-2010 (0.12 kg/m^2 annual relative increase, 95% CI: 0.06-0.19) than before 2009-2010 (0.07 kg/m^2 annual relative increase, 95% CI: 0.02-0.13). However, this difference was not statistically significant (p = 0.848). Annual changes in the prevalence of overweight and obesity were similar. The acceleration in the rise of obesity prevalence was mainly due to an increase in the prevalence of obesity among those who were in a better economic status (0.40% annual relative increase, 95% CI: -1.11%-1.93% vs. 2.97% annual relative increase, 95% CI: 1.75%-4.20%). Again, this difference was not significantly different (p = 0.985). Likewise, for the prevalence of overweight (including obesity), the annual increase was numerically faster after 2009-2010 than before 2009-2010 (0.6%, 95% CI: -0.08%-1.27% vs. 0.72%, 0.15%-1.29%; p = 0·584). Remarkably, the prevalence of overweight (including obesity) was nearly unchanged among those with poor economic conditions after 2009-2010 (0.00% annual relative increase, 95% CI: -0.96%-0.97%) compared with before 2009-2010 (1.82% annual relative increase, 95% CI: 0.55%-3.10%, p = 0.037). Meanwhile, both males and females with poor economic conditions had a slower increase in BMI and the prevalence of overweight and obesity after 2009-2010 compared with before 2009-2010. In contrast, a larger increase was found among those with good economic conditions after 2009-2010, although without statistical significance (p > 0.05).

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Table3. Annual change in BMI, overweight, obesity and economic status during 2003-2010 and 2011–2018

Characteristic	Male			Female			Both		
	2003/04-2009/2010	2011/12-2017/2018	p-value*	2003/2004-2009/2010	2011/2012-2017/2018	p-value*	2003/2004-2009/2010	2011/2012-2017/2018	p-value*
Change (95% CI) in mean BMI (kg/m²)									
Overall	0.07 (0.02, 0.13)	0.12 (0.06, 0.19)	0.848	0.65 (-0.01, 0.14)	0.13 (-0.39, 2.76)	0.846	0.07 (0.02, 0.13)	0.12 (0.06, 0.19)	0.848
PIR<130%	0.17 (0.02, 0.32)	0.08 (-0.06, 0.22)	0.245	0.17 (0.04, 0.30)	0.06 (-0.09, 0.21)	0.186	0.17 (0.05, 0.28)	0.07 (-0.04, 0.18)	0.170
PIR⩾130%	0.07 (-0.01, 0.14)	0.11 (0.04, 0.17)	0.716	0.15 (-0.04, 0.13)	0.16 (0.07, 0.25)	0.943	0.06 (0.00, 0.11)	0.13 (0.07, 0.20)	0.922
Percentage change (95% CI) in overweight prevalence									
Overall	0.69 (-0.18, 1.56)	0.50 (-0.24, 1.24)	0.393	0.50 (-0.45, 1.47)	0.95 (0.30, 1.60)	0.746	0.60 (-0.08, 1.27)	0.72 (0.15, 1.29)	0.584
PIR<130%	2.64 (-0.52, 4.82)	-0.06 (-1.60, 1.50)	0.050	1.33 (0.10, 2.56)	0.03 (-0.97, 1.04)	0.096	1.82 (0.55, 3.10)	0.00 (-0.96, 0.97)	**0.037**
PIR⩾130%	0.36 (-0.59, 1.31)	0.64 (-0.03, 1.33)	0.646	0.28 (-0.81, 1.40)	1.31 (0.55, 2.08)	0.900	0.30 (-0.50, 1.10)	0.95 (0.34, 1.56)	0.844
Percentage change (95% CI) in obesity prevalence									
Overall	1.93 (0.10, 3.76)	2.29 (0.54, 4.02)	0.589	1.15 (-0.39, 2.76)	1.71 (0.56, 2.84)	0.699	1.51 (0.24, 2.81)	1.99 (0.93, 3.04)	0.689
PIR<130%	3.16 (0.12, 6.19)	2.38 (-0.48, 5.25)	0.378	2.38 (0.34, 4.46)	0.95 (-0.77, 2.67)	0.192	2.56 (0.81, 4.31)	1.47 (0.00, 2.95)	0.223
PIR⩾130%	1.93 (-0.03, 3.85)	2.08 (-0.38, 3.77)	0.536	0.97 (-1.00, 3.00)	2.21 (0.62, 3.78)	0.796	0.40 (-1.11, 1.93)	2.97 (1.75, 4.20)	0.985

Abbreviations: BMI, body mass index; CI, confidence interval; PIR poverty income ratio.

* p-value for difference in annual changes for 2004-2010 versus 2011-2018.

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Graphical representations of the changes in the distribution of mean BMI and overweight and obesity prevalence are shown in Figure 1 and Figure 2. Figure 1 shows the changes in mean BMI across years stratified by age, PIR, education, and race. Similar trends in mean BMI were found across subgroups of age, PIR, education, race, sex, and physical activity status. Overall, the mean BMI generally increased over time among all participants. In the age subgroup, the lowest mean BMI was found in those aged 20–30 years, followed by those aged > 70 years (Table S2, Figure 1). Compared to good economic conditions, BMI was higher for those with poor economic conditions since 2005-2006. In 2017-2018, participants with poor economic conditions had a mean BMI 1.68 kg/m^2 lower than those with good economic conditions. Between 2003-2004 and 2017-2018, a lower mean BMI was found among participants with a higher educational level than among those with a lower educational level. A similar trend was found in the subgroup stratified by race. In 2017-2018, the mean (SE) BMI for all participants was 29.86 ± 0.26 kg/m^2, with the highest mean BMI in non-Hispanic Blacks (31.29 ± 0.29 kg/m^2) and the lowest BMI in other racial populations (28.21 ± 0.39 kg/m^2) (Table 1, Figure 1). Figure 2 shows the changes in mean BMI across years stratified by sex and activity status. Changes in overweight and obesity prevalence across years stratified by sex are also shown in Figure 2. From 2003-2004 to 2017-2018, the mean BMI increased similarly in both sexes, by approximately 1.61 kg/m^2 for males and 1.64 kg/m^2 for females (Table S2, Figure 2). Meanwhile, males had a lower BMI than females. In the physical activity status subgroup, there was a more complex pattern, with a decrease in mean BMI in 2011-2012 among those who were inactive and insufficiently active. Although there was an acceleration in the increase of mean BMI among those who were sufficiently active, their mean BMI was the lowest.

The trends in increasing obesity prevalence over time were largely consistent for males and

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females. In 2003-2004, males had a lower mean BMI and a lower prevalence of obesity than females, but the opposite pattern was seen in 2017-2018. In 2017-2018, males had a higher prevalence of obesity than females (43.3%, 95% CI: 38.2%-48.4% vs. 42.3%, 38.6%-46.0%) (Table S3, Figure 2).

The trends in increasing overweight prevalence over time were similar for both sexes. Overall, the overweight prevalence in males was higher than that in females. Between 2003-2004 and 2017-2018, the overweight (including obesity) increased similarly in both sexes, by approximately 1.61 kg/m^2 for males and 1.64 kg/m^2 for females. For overweight (including obesity) prevalence trends, there was an increasing prevalence among males from 70.6% (95% CI: 68.0%-73.0%) in 2003-2004 to 77.4% (95%CI: 73.9%-80.9%) in 2017-2018, and among females from 62.5% (95% CI: 59.9%-65.9%) to 70.5% (95% CI: 67.3%-73.6%) (Table S4, Figure 2).

4.Discussion

Our present study showed that the prevalence of obesity among American adults increased from 32.3% in 2003-2004 to 42.8% in 2017-2018. These results are broadly consistent with the results reported by the NCHS. In 2017-2018, the prevalence of obesity was 42.3% among males and 43.3% among females. Compared with 2003-2004, the mean BMI increased by 1.94 kg/m^2, obesity prevalence increased by 15%, and overweight prevalence increased by 8% in 2017-2018 after adjusting for age, sex, race, education, PIR, and physical activity status. The increases in mean BMI and the prevalence of both overweight and obesity were somewhat larger after 2009-2010 than before 2009-2010. However, the difference was not statistically significant.

The levels and changes in trends of mean BMI and obesity prevalence among American adults have been covered by numerous studies [9, 15, 27-29]. The NCHS reported that the age-adjusted obesity prevalence among adults was 42.4% in 2017-2018, and obesity prevalence increased among

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adults from 1999-2000 through 2017-2018 [15]. Another study using data from the 2005–2014 NHANES also showed that a statistically significant positive linear trend in obesity prevalence was present in females but not in males [28]. One recent study suggested that the prevalence of obesity among US adults increased from 35.4% in 2011-2012 to 43.4% in 2017-2018. From 2011-2012 through 2017-2018, the mean BMI increased from 28.7 kg/m^2 to 29.8 kg/m^2 [29]. Our results were broadly consistent with the results of the above studies at each timepoint. However, our present study used a larger sample size as well as a longer time span than the above studies.

To the best of our knowledge, few studies have assessed annual changes in BMI and obesity prevalence and the potential effects of the 2008–2009 global financial crisis among US adults. A previous study conducted using NHANES data from 1999–2008 showed that the increases in the prevalence of obesity do not appear to be continuing at the same rate from 1999-2000 through 2007-2008. When they adjusted for age and race with survey period as a categorical variable, there were no significant differences in the prevalence of obesity between 2003-2004 and 2007-2008 for males [27]. This is broadly consistent with our findings. In our study, statistically significant differences in mean BMI and obesity prevalence for both sexes were found since 2009-2010 (Table 2). Furthermore, a previous study evaluated the effects of the economic crisis on dietary quality and obesity rates [30]. They found that economic changes can modify diet quality and increase the risk of having a poor diet or being obese, which was mainly due to the changes in economic and work conditions. In our study, the impact of economic conditions on BMI was complex. A significant increase in mean BMI was found among both the poor and the rich. The overall BMI was higher for those with poor economic conditions since 2005-2006 than for those with good economic conditions (Figure 1). However, the acceleration in the increase of obesity prevalence was mainly due to an increase in the prevalence of

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obesity among those who are in a better economic status (Table 3). Interestingly, there was no significant difference in the annual change in obesity prevalence before and after the financial crisis. This may be mainly due to the increase in the proportion of the poor after the financial crisis. The proportion of the poor increased from 21.68% in 2009-2010 to 24.6% in 2011-2012. This trend continued until 2015. In our present study, although the differences were not statistically significant, numerical larger increases in mean BMI and the prevalence of both overweight and obesity were found after 2009-2010 than before 2009-2010.

Interestingly, participants in the highest daily total energy intake tertile had the lowest BMIs compared with those in the lowest daily total energy intake tertile (28.97 kg/m^2 vs. 29.30 kg/m^2). The findings were similar for the prevalence of obesity (36.7% vs. 39.9%) and overweight (69.8% vs. 70.9%). Thus, we analysed the characteristics of the participants according to tertiles of daily total energy intake (Table S8). Compared with those in the lowest daily total energy intake tertile, participants in the highest daily total energy intake tertile had higher proportions of non-Hispanic Whites and individuals who were college educated (college degree or higher), sufficiently physically active, and had good economic status. This might in part be related to the lower BMI and prevalence of obesity.

In addition, although the mean BMI and the prevalence of overweight and obesity increased over time, the mean daily total energy intake decreased from 2003-2004 to 2017-2018 (2,113.90±7.96 Kcal/d vs. 1,980.34±7.96 Kcal/d, $p < 0.001$). Several mechanisms may explain this phenomenon: (1) The reduction in energy intake may lead to hunger increases and energy expenditure declines, leading to physiological adaptations that tend to push body weight back up [31] ; and (2) In the US, carbohydrate intake has increased markedly, resulting in major increases in the proportion of calories

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from carbohydrates [32]. A high-carbohydrate diet could produce postprandial hyperinsulinaemia, which promotes energy storage and causes an increase in body weight [33].

In our study, a lower mean BMI was found among participants with a higher educational level than among those with a lower educational level. A previous study showed that a higher educational level is related to a lower BMI level among middle-aged females, mainly on account of selection [34]. Theories of selection note that low-BMI children tend to have higher grades and test scores, and better chances of completing secondary and tertiary education. It has also been reported that young overweight or obese females are more likely to have a lower educational level [34]. This might be explained by the following reasons: (1) Children with a lower BMI tend to come from socioeconomically advantaged families, and have better chances of completing their studies [34]; (2) Children with a lower BMI may benefit from physical activity, which may have a positive influence on academic performance [35]; and (3) Negative views on high-BMI children may impair their academic performance [36]. Our results also show that females had a higher prevalence of obesity than males. This may be due to oestrogen-reducing postprandial fatty acid oxidation, leading to an increase in body fat among females.[37] Meanwhile, it was less likely for females to be physically active than for males.

In our study, approximately 67.4% of participants reported meeting physical activity guidelines in 2017-2018. As reported by the NCHS, 53.3% of adults aged ≥ 18 years met the 2018 Physical Activity Guidelines for Americans for aerobic physical activity. However, the NCHS estimates were limited to leisure-time physical activity only. Our estimates were based on the Global Physical Activity Questionnaire, including both daily activities (work activities) and leisure time activities. For this reason, our estimates were larger than those reported by NCHS reports.

Although NHANES is designed to provide nationally representative estimates, it is a repeated

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cross-sectional survey, which precludes within-individual change in BMI or obesity. Meanwhile, obesity was defined mainly based on measurements of BMI, which does not measure body fat directly. Although BMI is highly correlated with overall body fat [38], the relationship between BMI and body fat varies by sex, age, and race-ethnicity [39]. In addition, the study used a large nationally representative sample of adults from the US. Thus, our results are only generalizable to the US population. Therefore, there are certain limitations in the extrapolation of the study results.

The COVID-19 global pandemic has changed the lifestyle of most Americans. It has been reported that approaches designed to contain the spread of COVID-19, such as lockdowns, might exacerbate the prevalence of obesity [40]. The effects of the COVID-19 global pandemic on BMI and the prevalence of obesity have yet to be examined. Regrettably, information about anthropometric measurements in NHANES after 2018 has not been released. Additional follow-up studies are required to answer these questions.

5. Conclusions

Although the prevalence of adult obesity continues to rise, there have been no significant changes in the annual growth of adult obesity prevalence between 2003-2004 and 2017-2018. In 2017-2018, the prevalence of obesity was 42.8%, which equates to 76 million Americans at risk for serious and costly chronic conditions. The prevalence of obesity was higher among older adults (aged 60-69 years), females, non-Hispanic Blacks, and participants who did not graduate college, were physically inactive, reported lower daily total energy intake, and had poor economic status.

Author contributions:

WG, ZL: designed the research; ZL and ML: analyzed the data; ZL: wrote the paper; ZL: had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy

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of the data analysis; WG, ZL, ML, and SW: assisted with interpretation of the results and critically reviewed the manuscript; and all authors: read and approved the final manuscript. The authors report no conflicts of interest.

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Competing interests statement

None.

Data sharing statement

Data described in the article are publicly and freely available without restriction at https://www.cdc.gov/nchs/nhanes/index.htm.

Ethics approval

Approval was obtained from the National Center for Health Statistics Research Ethics Review Board, and all participants provided written informed consent (Approval number: Protocol#98-12, #2005-06, #11-17, #18-01, https://www.cdc.gov/nchs/nhanes/irba98.htm).

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Figure legends

Figure1 Mean BMI by age (A), poverty income ratio (B), education (C) and race (D) group from 2003 through 2018.

Figure2 Mean BMI by sex (A), physical activity status (B)group and prevalence of overweight (C) and obesity (D) from 2003 through 2018.

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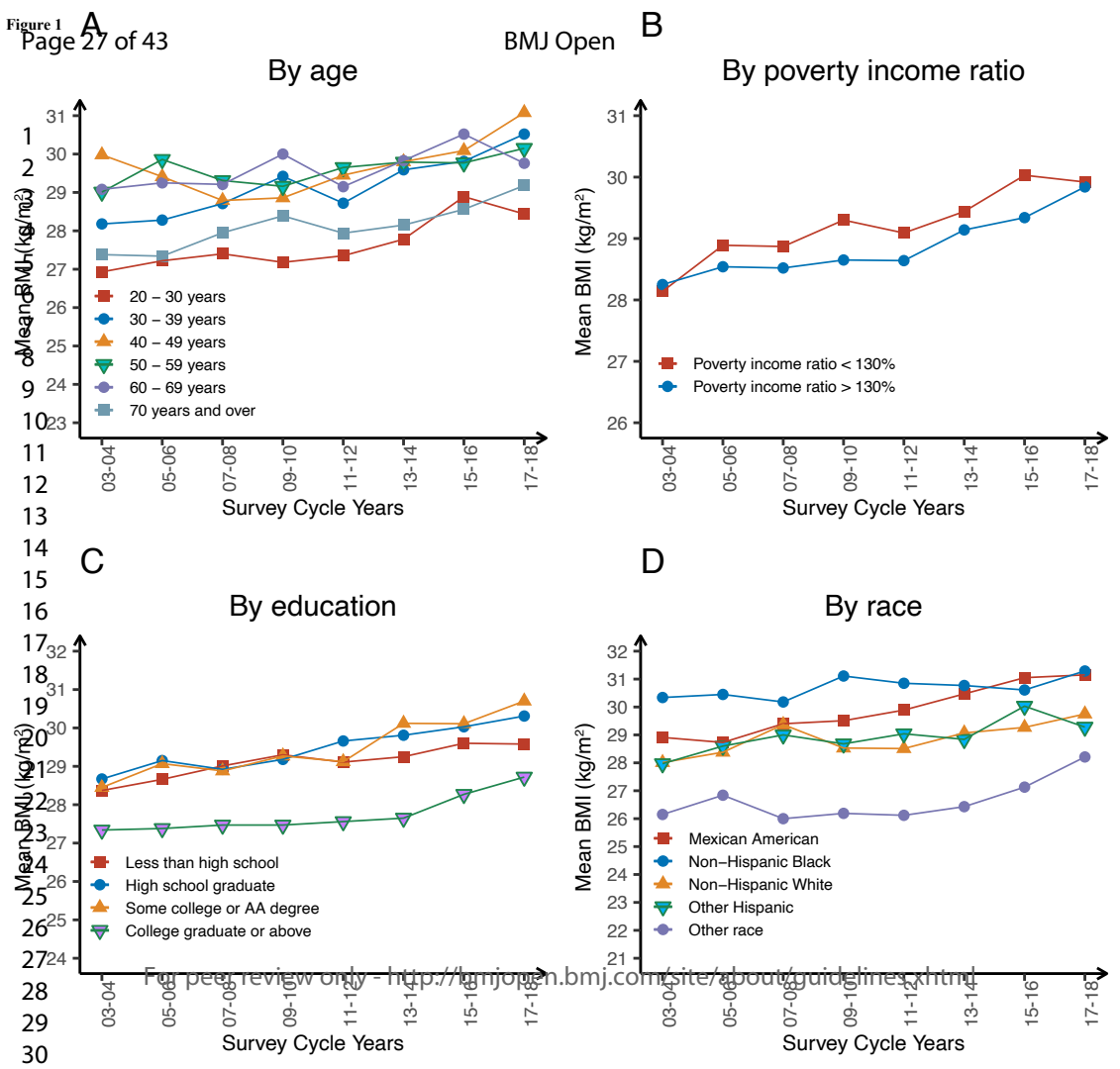

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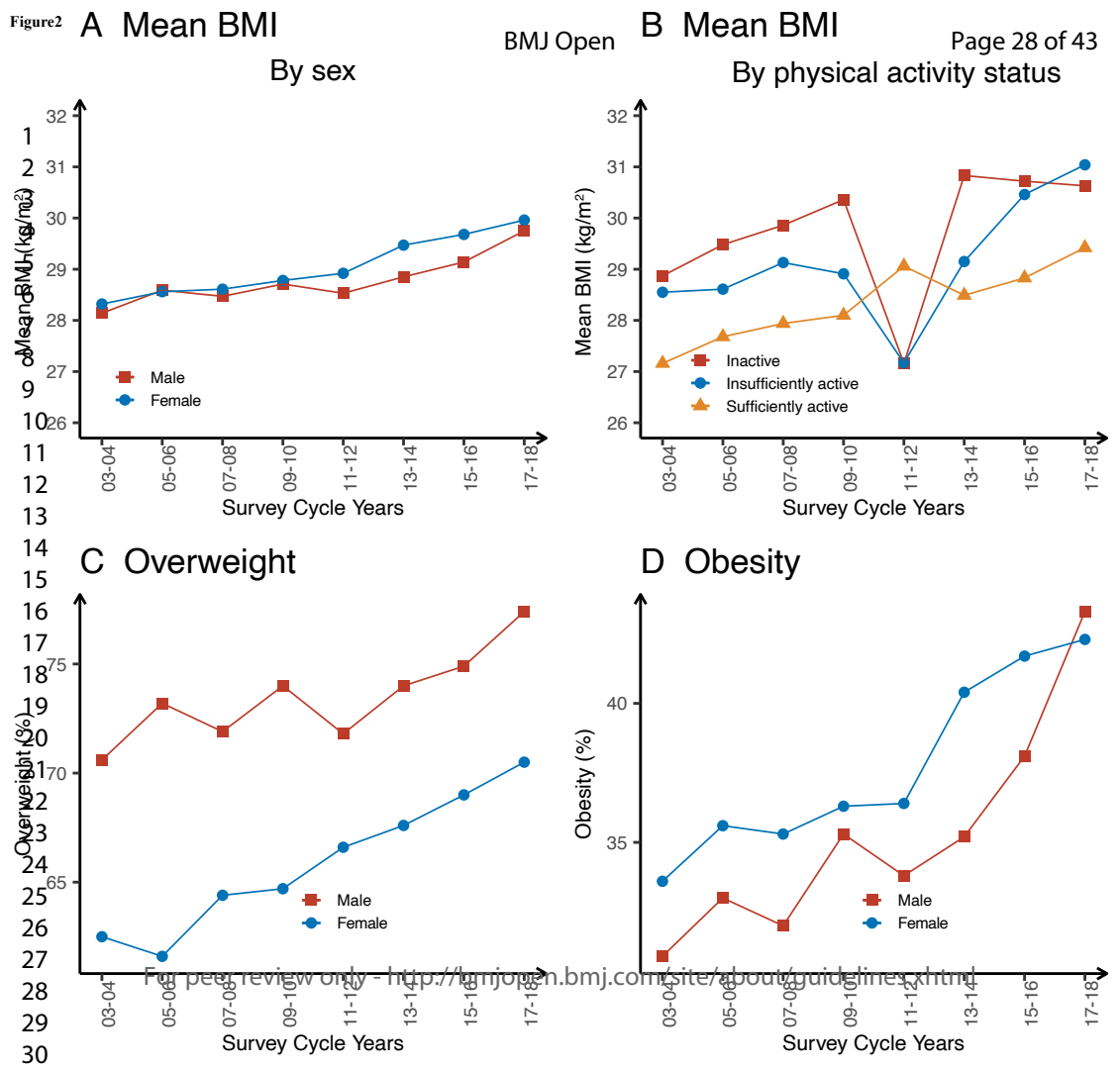

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Supplementary material

TITLE: Trends in body mass index, overweight and obesity among adults in the United States, the NHANES from 2003 through 2018: a repeat cross-sectional survey

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For the annual change in mean BMI and annual relative change in the prevalence of obesity and overweight, the calculation formulas were as follows:

- Annual change in mean BMI (kg/m^2):

$$\text{annual change} = = \frac{(\text{level}_{t2} - \text{level}_{t1})}{(t2 - t1)} \boxed{\frac{(\text{level}_{t2} - \text{level}_{t1})}{(t2 - t1)}}$$

- Annual relative change in the prevalence of overweight and obesity:

$$\text{annual change} = \left(\frac{\text{level}_{t2}}{\text{level}_{t1}}\right)^{\frac{1}{t2-t1}} - 1$$

Table S1. Characteristics of participants according to BMI groups*

Characteristic	Total (n=42,266)	BMI, kg/m² †			p-value
		< 25 (n=12,522)	25.0-29.9 (n=14,046)	⩾ 30 (n=1,5698)	
Age, years	47.11 ± 0.20	44.29 ± 0.30	48.78± 0.24	47.99 ± 0.22	< 0.001
Age, years, n (%)					<0.001
20 - 30	8,033 (20.54)	3,396 (29.24)	2,180 (16.73)	2,457 (16.63)	
30 - 39	7,175 (18.37)	2,104 (18.37)	2,334 (18.12)	2,737 (18.61)	
40 - 49	7,035 (19.43)	1,772 (16.64)	2,408 (20.50)	2,855 (20.84)	
50 - 59	6,714 (18.11)	1,675 (15.60)	2,224 (18.28)	2,815 (20.08)	
60 - 69	6,629 (12.76)	1,521 (9.62)	2,340 (13.84)	2,768 (14.43)	
≥ 70	6,680 (10.78)	2,054 (10.54)	2,560 (12.53)	2,066 (9.41)	
Sex, n (%)					< 0.001
Male, n (%)	20,408 (47.97)	5,784 (41.87)	7,773 (55.66)	6,851 (46.17)	
Female, n (%)	21,858 (52.03)	6,738 (58.13)	6,273 (44.34)	8,847 (53.83)	
Race, n (%)					< 0.001
Mexican American	6,805 (8.38)	1,355 (5.61)	2,581 (9.35)	2,869 (9.86)	
Other Hispanic	3,755 (5.33)	917 (4.51)	1,412 (6.04)	1,426 (5.38)	
Non-Hispanic White	18,120 (67.36)	5,735 (69.30)	6,070 (67.90)	6,315 (65.24)	
Non-Hispanic Black	9,094 (11.41)	2,268 (9.24)	2,624 (9.82)	4,202 (14.70)	
Other Race	4,492 (7.51)	2,247 (11.35)	1,359 (6.89)	886 (4.82)	
Education, n (%)					< 0.001
Less than high school	10,814 (16.4)	2,899 (15.19)	3,779 (16.79)	4,136 (16.95)	
High school graduate	9,787 (23.6)	2,747 (21.39)	3,200 (23.25)	3,840 (25.84)	
Some college or AA degree	12,266 (31.4)	3,409 (29.03)	3,860 (29.85)	4,997 (34.71)	
College graduate or above	9,345 (28.6)	3,441 (34.26)	3,194 (30.06)	2,710 (22.43)	
Poverty income ratio, n (%)					< 0.001
< 130%	12,129 (21.29)	3,588 (21.83)	3,802 (19.69)	4,739 (22.28)	
≥ 130%	26,450 (78.71)	7,863 (78.17)	8,944 (80.31)	9,643 (77.72)	
BMI, kg/m²	28.93 ±0.07	22.20 ± 0.02	27.44 ±0.02	35.98 ±0.07	
Total energy intake, Kcal/d	2,027.31±7.96	2051.4 ±12.7	2049.5 ± 12.8	1988.0 ± 11.1	< 0.001
Total energy intake, n (%)					< 0.001
Tertile1	9,991 (25.36)	2,614 (24.87)	3,245 (23.89)	4,132 (27.06)	
Tertile2	8,990 (27.08)	2,609 (26.89)	3,080 (28.30)	3,301 (26.16)	
Tertile3	15,644 (47.56)	4,673 (48.24)	5,180 (47.81)	5,791 (46.79)	
Physical activity, n (%)					< 0.001
Inactive	8,504 (18.09)	2,138 (14.52)	2,744 (16.99)	3,622 (22.15)	
Insufficiently active	6,649 (17.52)	1,995 (17.40)	2,232 (17.63)	2,422 (17.51)	
Sufficiently active	23,320 (64.39)	7,295 (68.09)	7,761 (65.38)	8,264 (60.34)	

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination

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Survey (2003-2018).

† Values are presented as mean ± SE for continuous variables and unweighted numbers (weighted %) for categorical variables.

Abbreviations: AA, Associate of Arts; BMI, body mass index

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Table S2. Mean BMI over time among adults in the United States, 2003-2018 *

Characteristics	BMI (weighted mean ± SE), kg/m^2								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Overall	28.93 ± 0.07	28.24 ± 0.15	28.57 ± 0.23	28.54 ± 0.16	28.75 ± 0.13	28.73 ± 0.21	29.17 ± 0.17	29.42 ± 0.25	29.86 ± 0.26
Age, years									
20 - 30	27.54 ± 0.14	26.93 ± 0.21	27.22 ± 0.34	27.40 ± 0.45	27.18 ± 0.30	27.35 ± 0.38†	27.78 ± 0.42†	28.89 ± 0.39‡	28.44 ± 0.55‡
30 - 39	29.16 ± 0.13	28.18 ± 0.37	28.28 ± 0.36	28.71 ± 0.28	29.42 ± 0.32	28.72 ± 0.33	29.59 ± 0.35†	29.81 ± 0.31‡	30.52 ± 0.48‡
40 - 49	29.53 ± 0.13	28.98 ± 0.28	29.41 ± 0.32	28.79 ± 0.27	28.86 ± 0.22	29.45 ± 0.35	29.80 ± 0.42	30.09 ± 0.52†	31.08 ± 0.36‡
50 - 59	29.61 ± 0.14	29.01 ± 0.41	29.86 ± 0.43†	29.31 ± 0.42	29.16 ± 0.24	29.65 ± 0.51	29.79 ± 0.31†	29.77 ± 0.40	30.15 ± 0.32‡
60 - 69	29.66 ± 0.13	29.08 ± 0.23	29.25 ± 0.29	29.21 ± 0.33	30.00 ± 0.29	29.15 ± 0.40	29.83 ± 0.32	30.52 ± 0.40†	29.76 ± 0.46
≥ 70	28.16 ± 0.10	27.38 ± 0.23	27.34 ± 0.25	27.95 ± 0.25†	28.39 ± 0.22‡	27.94 ± 0.31‡	28.15 ± 0.24‡	28.56 ± 0.35‡	29.18 ± 0.26‡
Sex									
Male	28.79 ± 0.08	28.14 ± 0.13	28.59 ± 0.25	28.47 ± 0.16	28.71 ± 0.21	28.53 ± 0.23	28.85 ± 0.15	29.14 ± 0.26‡	29.75 ± 0.27‡
Female	29.07 ± 0.09	28.32 ± 0.24	28.56 ± 0.28	28.61 ± 0.20	28.78 ± 0.14†	28.92 ± 0.23‡	29.47 ± 0.26‡	29.68 ± 0.29‡	29.96 ± 0.37‡
Race									
Mexican American	29.96 ± 0.13	28.91 ± 0.39	28.73 ± 0.22	29.40 ± 0.31	29.51 ± 0.27	29.89 ± 0.38	30.47 ± 0.24‡	31.05 ± 0.33‡	31.15 ± 0.35‡
Other Hispanic	29.05 ± 0.15	27.97 ± 0.64	28.60 ± 0.51	29.00 ± 0.41	28.68 ± 0.41	29.04 ± 0.31‡	28.84 ± 0.50	30.03 ± 0.40‡	29.28 ± 0.33‡
Non-Hispanic White	28.73 ± 0.09	28.01 ± 0.18	28.38 ± 0.25	28.37 ± 0.26	28.53 ± 0.16‡	28.51 ± 0.28‡	29.07 ± 0.19‡	29.27 ± 0.26‡	29.75 ± 0.35‡
Non-Hispanic Black	30.72 ± 0.11	30.34 ± 0.31	30.45 ± 0.28	30.18 ± 0.30	31.11 ± 0.35	30.85 ± 0.28	30.77± 0.31	30.61± 0.34	31.29 ± 0.29†
Other race	26.77 ± 0.16	26.15 ± 0.52	26.84 ± 0.65	26.00 ± 0.55	26.19 ± 0.39	26.12 ± 0.41	26.43 ± 0.36	27.13 ± 0.42	28.21 ± 0.39‡
Education									
Less than high school	29.09 ± 0.09	28.37 ± 0.32	28.66 ± 0.16	29.01 ± 0.25	29.30 ± 0.22‡	29.11 ± 0.28‡	29.25 ± 0.21‡	29.60 ± 0.29‡	29.58 ± 0.37‡
High school graduate	29.47 ± 0.10	28.67 ± 0.20	29.15 ± 0.27	28.92 ± 0.29	29.18 ± 0.20†	29.66 ± 0.37†	29.81 ± 0.33‡	30.03 ± 0.38‡	30.31 ± 0.18‡

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Some college or AA degree	29.51 ± 0.10	28.45 ± 0.22	29.07± 0.29	28.88 ± 0.25	29.27 ± 0.17†	29.12 ± 0.28†	30.12 ± 0.27‡	30.11 ± 0.33‡	30.70 ± 0.32‡
College graduate or above	27.78 ± 0.11	27.34 ± 0.33	27.38 ± 0.37	27.40 ± 0.28	27.47 ± 0.30	27.56 ± 0.34†	27.65 ± 0.20†	28.27 ± 0.26‡	28.72 ± 0.43‡
Poverty income ratio									
< 130%	28.14 ± 0.22	28.14 ± 0.22	28.89 ± 0.31†	28.87 ± 0.28†	29.30± 0.34‡	29.09± 0.21‡	29.44± 0.21‡	30.03 ± 0.32‡	29.92 ± 0.39‡
≥ 130%	28.25 ± 0.15	28.25 ± 0.15	28.54 ± 0.24	28.52 ± 0.16	28.65 ± 0.15†	28.64 ± 0.26‡	29.14 ± 0.23‡	29.34 ± 0.27‡	28.24 ± 0.15‡
Physical activity									
Inactive	28.53 ± 0.09	28.87 ± 0.72	29.48 ± 0.82	29.86 ± 0.21	30.36 ± 0.21	27.16 ± 0.35†	30.83 ± 0.30†	30.72± 0.33†	30.63 ± 0.39†
Insufficiently active	28.98 ± 0.12	28.55 ± 0.20	28.61 ± 0.28	29.13 ± 0.34	28.91 ± 0.21	27.17 ± 0.38‡	29.15 ± 0.32	30.46 ± 0.58‡	31.04 ± 0.42‡
Sufficiently active	28.53 ± 0.09	27.16 ± 0.23	27.68 ± 0.27	27.94 ± 0.20†	28.10± 0.18‡	29.06 ± 0.22‡	28.49 ± 0.17‡	28.83 ± 0.25‡	29.42 ± 0.29‡
Total energy intake									
Tetile 1	29.30 ± 0.11	28.51 ± 0.19	29.21 ± 0.30	28.66 ± 0.24	29.37 ± 0.25‡	29.04 ± 0.31†	29.58 ± 0.34‡	29.83 ± 0.33‡	29.91 ± 0.35‡
Tetile 2	28.95 ± 0.11	27.94 ± 0.22	28.78 ± 0.26‡	28.49 ± 0.27‡	28.81 ± 0.23‡	28.92 ± 0.23‡	29.25 ± 0.34‡	29.31 ± 0.34‡	29.98 ± 0.45‡
Tetile 3	28.97 ± 0.10	28.53 ± 0.29	28.37 ± 0.36	28.72 ± 0.19	28.52 ± 0.24	28.84 ± 0.34†	29.14 ± 0.22†	29.65 ± 0.23‡	29.96 ± 0.27‡

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003–2018). († $p < 0.05$; ‡ $p < 0.01$)

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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Table S3. Prevalence of obesity over time among adults in the United States, 2003-2018 *

Characteristics	Prevalence (95CI),%								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Overall	36.7 (35.7, 37.6)	32.3 (29.9, 34.6)	34.4 (31.6, 37.2)	33.7 (31.5, 35.9)	35.8 (34.0, 37.7)	35.2 (32.4, 37.9)	37.9 (36.2, 39.6)	40.0 (37.0, 43.0)	42.8 (39.5, 46.1)
Age, years									
< 30	29.6 (27.9, 31.4)	26.1 (23.1, 29.0)	27.7 (22.7, 32.6)	27.4 (21.6, 33.2)	27.7 (24.0, 31.4)	29.0 (23.9, 34.1)	29.5 (25.8, 33.1)	31.7 (26.7, 36.7) ‡	37.5 (30.2, 44.8) ‡
30 - 39	37.1 (35.5 ,38.7)	32.5 (27.6, 37.5)	31.1 (26.6, 35.6)	35.5 (30.5, 39.7)	39.7 (35.4, 44.1) †	33.5 (30.2, 36.9)	39.9 (35.9, 43.9) †	40.5 (37.0, 44.1) †	44.3 (38.8, 49.9) ‡
40 - 49	39.3 (37.7, 40.9)	36.7 (34.2, 39.2)	39.0 (34.4, 43.6)	33.7 (29.4, 38.1)	36.2 (33.0, 39.5)	38.8 (33.4, 44.2)	41.1 (35.7, 46.5)	44.0 (38.1, 49.8) †	46.3 (41.7, 51.0) ‡
50 - 59	40.5 (38.6, 42.4)	35.9 (29.6, 42.1)	43.2 (38.6, 47.7)	38.1 (32.5, 43.6)	37.2 (33.8, 40.5)	39.5 (33.2, 45.9)	41.7 (37.1, 46.3)	42.7 (35.8, 49.6)	44.9 (40.7, 49.1) ‡
60 - 69	41.6 (39.6, 43.6)	35.7 (32.1, 39.3)	38.7 (34.1, 43.3)	38.6 (34.4, 42.8)	43.8 (39.7, 48.0) ‡	39.5 (34.5, 44.6) ‡	42.9 (38.9, 46.9) †	46.0 (40.3, 51.6) ‡	43.3 (35.3 ,51.4) †
≥ 70	32.2 (30.7, 33.6)	26.2 (22.4, 30.0)	25.8 (21.4, 30.2)	30.9 (27.0, 34.8) †	33.4 (30.0, 36.8) ‡	29.5 (26.4, 32.7) ‡	32.7 (28.4 ,37.0) ‡	35.5 (30.9, 40.1) ‡	40.3 (36.0, 44.6) ‡
Sex									
Men	35.3 (34.1, 36.6)	30.9 (28.4 ,33.4)	33.0 (28.9, 37.1)	32.0 (29.1, 34.8)	35.3 (31.9, 38.7) †	33.8 (31.2, 36.4)	35.2 (33.2, 37.2) ‡	38.1 (33.9, 42.3) ‡	43.3 (38.2, 48.4) ‡
Women	37.9 (36.8, 38.9)	33.6 (30.3, 36.8)	35.6 (33.0, 38.3)	35.3 (33.0, 37.6)	36.3 (34.5, 38.1) †	36.4 (33.0, 39.8) ‡	40.4, 37.9, 43.0) ‡	41.7 (38.7, 44.7) ‡	42.3 (38.6, 46.0) ‡
Race									
Mexican American	43.1 (41.5, 44.8)	36.3 (31.2, 41.4)	33.3 (31.6, 35.1)	39.2 (32.2, 46.2)	38.9 (36.4, 43.4)	45.2 (40.7, 49.7) ‡	46.7 (42.5, 51.0) ‡	49.0 (45.6, 52.4) ‡	51.6 (47.5, 55.8) ‡
Other Hispanic	37.0 (35.0, 39.1)	29.5 (19.2, 39.8)	34.2 (26.6, 41.9)	34.9 (30.3, 39.6)	34.7 (28.8, 40.6)	38.1 (32.7, 43.6) ‡	36.9 (31.2, 42.6) †	44.2 (38.4, 49.9) ‡	37.0 (42.7, 41.2) ‡
Non-Hispanic White	35.5 (34.4, 36.6)	31.0 (28.5, 33.4)	33.3 (30.2, 36.5)	32.6 (29.2, 36.0)	34.7 (32.4, 37.1) ‡	33.4 (29.9, 37.0) ‡	37.0 (35.0, 39.1) ‡	38.9 (35.7, 42.1) ‡	43.0 (38.2, 47.7) ‡
Non-Hispanic Black	47.1 (45.7, 48.5)	45.2 (40.9, 49.4)	45.4 (42.0, 48.8)	43.6 (39.6, 47.5)	49.9 (45.1, 54.7)	47.8 (44.3, 51.2)	47.9 (43.8, 52.1)	46.8 (42.5, 51.1)	49.8 (46.9, 52.7)
Other race	23.7 (21.4, 25.9)	19.0 (9.9, 28.0)	26.4 (17.6, 35.2)	19.4 (9.9, 29.0)	19.7 (15.4, 24.0)	18.8 (13.9, 23.8)	21.4 (16.7, 26.0)	28.0 (21.3, 36.7)	30.6 (25.5, 35.7) †
Education									
Less than high school	37.9 (36.7, 39.2)	34.3 (30.0, 38.5)	35.7 (33.3, 38.1)	37.6 (33.1, 42.0)	37.6 (34.9, 40.3) †	37.7 (35.1, 40.4) †	40.6 (37.5, 43.6)	40.3 (36.3, 43.7) ‡	41.4 (37.3, 45.6) †
High school graduate	40.0 (38.5, 41.4)	34.3 (30.5, 38.1)	38.9 (35.1, 42.6)	35.0 (31.6, 38.4)	38.3 (34.6, 42.0)	40.3 (35.3, 45.5) †	41.3 (37.0, 45.7) ‡	43.7 (38.6, 48.9) ‡	47.2 (43.2, 51.2) ‡

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Some college or AA degree	40.7 (39.4, 41.9)	33.9 (30.4, 37.4)	36.8 (32.9, 40.7)	37.5 (34.4, 40.6)	40.6 (38.3, 42.9) ‡	38.0 (34.0, 41.9) †	42.9 (40.1, 45.7) ‡	46.0 (42.2, 49.8) ‡	47.7 (43.8, 51.5) ‡
College graduate or above	28.8 (27.2, 30.4)	26.3 (22.0, 30.7)	26.2 (21.9, 30.5)	24.9 (20.9, 28.9)	27.5 (23.7, 31.4)	27.6 (22.5, 32.8)	28.7 (26.2, 31.3) †	31.5 (27.5, 35.4) ‡	34.7 (29.1, 40.2) ‡
Poverty income ratio									
< 130%	38.4 (37.2, 39.6)	32.3 (29.7, 34.6)	36.3 (33.1, 39.6) ‡	35.9 (32.1, 39.7) †	38.4 (34.8, 41.9) ‡	38.0 (35.5, 40.6) ‡	39.4 (36.9, 41.8) ‡	42.0 (38.1, 45.9) ‡	43.8 (39.7, 47.9) ‡
≥ 130%	36.4 (35.3, 37.4)	32.3 (29.6, 34.9)	34.3 (31.0, 37.6)	33.1 (30.9, 35.4)	35.7 (33.4, 37.9) †	34.3 (31.0, 37.6) †	37.6 (35.3, 40.0) ‡	39.8 (36.3, 43.2) ‡	43.1 (39.6, 46.7) ‡
Physical activity									
Inactive	44.8 (43.4, 46.2)	38.0 (30.4, 45.6)	41.7 (29.5, 53.9)	42.6 (39.7, 45.4)	44.4 (42.4, 46,4)	26.2 (20.0, 32.3) †	48.5 (44.9, 52.1) †	48.0 (44.5, 51.5) †	46.7 (43.1, 50.4) †
Insufficiently active	36.4 (34.8, 38.0)	33.7 (30.6, 36.7)	34.0 (30.8, 37.3)	36.3 (31.1, 41.4)	37.3 (33.0, 41.6)	27.4 (22.0, 32.8) †	36.9 (33.6, 40.1)	44.5 (37.2, 51.8) ‡	48.3 (41.7, 54.9) ‡
Sufficiently active	34.3 (33.2,35.4)	24.8 (21.5, 28.2)	29.1 (24.9, 33.4)	30.0 (27.5, 32.5) †	32.3 (29.7, 34.9) ‡	36.9 (34.2, 39.5) ‡	33.7 (31.9, 35.5) ‡	36.6 (33.4, 39.7) ‡	40.6 (36.7, 44.6) ‡
Total energy intake									
Tetile 1	39.9 (38.4,41.3)	34.5 (32.2, 36.8)	38.2 (34.8, 41.7)	36.1 (33.1, 39.0)	39.3 (36.1, 42.5) ‡	38.5 (33.6, 43.4)	40.8 (36.2, 45.3) ‡	43.4 (39.2, 47.6) ‡	46.1 (41.4, 50.8) ‡
Tetile 2	36.0 (34.5, 37.6)	30.1 (26.7, 33.4)	35.8 (31.7, 39.8) †	32.1 (28.5, 35.7)	36.1 (32.8, 39.4) †	34.7 (31.4, 38.1) ‡	38.0 (33.4, 42.7) ‡	37.9 (33.2, 42.7) ‡	43.3 (37.1, 49.4) ‡
Tetile 3	36.7 (35.5, 38.0)	33.9 (29.9, 37.8)	32.6 (28.4, 36.9)	34.8 (32.0, 37.6)	35.0 (31.6, 38.4)	35.4 (31.6, 39.3) †	37.5 (34.8, 40.2) †	41.3 (37.6, 45.1) ‡	43.3 (39.4, 47.2) ‡

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003–2018). († $p < 0.05$; ‡ $p < 0.01$)

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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Table S4. Prevalence of overweight over time among adults in the United States, 2003-2018 *

Characteristics	Prevalence (95CI),%								
	Total (n= 42,266)	**2003/2004 (n = 4,647)**	**2005/2006 (n = 4,680)**	**2007/2008 (n = 5,607)**	**2009/2010 (n = 5,994)**	**2011/2012 (n = 5,237)**	**2013/2014 (n = 5,520)**	**2015/2016 (n = 5,406)**	**2017/2018 (n = 5,175)**
Overall	69.6 (68.7, 70.5)	66.3 (64.4, 68.3)	67.2 (64.6, 69.8)	68.0 (66.2, 69.8)	69.2 (66.6, 71.7)	69.1 (65.9, 72.3)	70.7 (69.0, 72.3)	71.8 (68.9, 74.8)	73.8 (71.1, 76.4)
Age, years									
20 - 30	56.6 (54.7, 58.5)	53.4 (49.1, 57.6)	56.4 (51.9, 60.8)	55.2 (51.1, 59.3)	56.7 (50.7, 62.7)	54.9 (47.4, 62.3)	56.6 (52.4, 60.9)	59.7 (55.3, 64.1)†	59.4 (53.2, 65.5)†
30 - 39	69.8 (68.1, 71.4)	63.0 (57.7, 68.4)	64.6 (59.1, 70.0)	69.3 (65.9, 72.8)	70.7 (67.0, 74.5) †	68.6 (64.4, 72.7)	72.3 (68.2, 76.3) ‡	73.2 (69.5, 76.8) ‡	76.2 (70.6, 81.8) ‡
40 - 49	74.0 (72.4, 75.5)	73.9 (69.2, 78.6)	70.2 (66.2, 74.2)	71.4 (67.6, 75.3)	69.6 (66.4, 72.9)	75.9 (71.7, 80.1)	76.6 (73.0, 80.2)	73.9 (68.7, 79.0)	80.9 (75.5, 86.3)
50 - 59	74.0 (72.4, 75.6)	71.1 (66.7, 75.5)	75.5 (91.0, 79.9)	71.9 (66.7, 77.1)	74.3 (70.0, 78.5)	75.2 (70.6, 79.8)	74.6 (72.2, 77.0)	74.1 (69.6, 78.7)	74.8 (69.3, 80.4)
60 - 69	77.1 (75.4, 78.8)	76.7 (73.4, 80.1)	76.7 (71.7, 81.6)	75.5 (71.4, 79.6)	78.6 (74.7, 82.5)	74.4 (68.3, 80.6)	76.0 (72.5, 79.5)	80.1 (74.5, 85.7)	78.1 (73.6, 82.5)
≥ 70	70.2 (68.9, 71.4)	65.6 (61.0, 70.2)	63.9 (60.4, 67.4)	69.1 (65.8, 72.4)	71.0 (68.2, 73.8) †	67.4 (63.8, 70.9) †	70.8 (68.2, 73.4) †	73.8 (70.2, 77.4) ‡	77.1 (73.5, 80.7) ‡
Sex									
Male	73.5 (72.5, 75.6)	70.6 (68.0, 73.0)	73.2 (70.3, 76.2)	71.9 (70.1, 73.7)	74.0 (70.4, 77.6)	71.8 (68.6, 75.0)	74.0 (71.9, 76.1) †	74.9 (72.0, 77.8) †	77.4 (73.9, 80.9) ‡
Female	66.0 (64.9, 67.1)	62.5 (59.9, 65.9)	61.6 (58.3, 64.8)	64.4 (61.7, 67.1)	64.7 (62.3, 67.1)	66.6 (63.0, 70.2) ‡	67.6 (65.2, 70.0) ‡	69.0 (65.4, 72.6) ‡	70.5 (67.3, 73.6) ‡
Race									
Mexican American	79.7 (78.1, 81.2)	73.8 (67.8, 79.8)	73.4 (69.8, 77.0)	77.3 (73.3, 81.2)	79.9 (76.5, 83.3)	78.6 (72.7, 84.5)	83.2 (80.1, 86.3) †	82.8 (78.9, 86.8) ‡	85.3 (80.8, 89.9) ‡
Other Hispanic	74.6 (72.9, 76.3)	68.4 (58.1, 78.7)	70.5 (62.3, 78.8)	74.8 (69.5, 80.1)	72.2 (69.4, 75.1)	75.2 (71.8, 78.7)	70.0 (64.7, 75.2)	78.5 (74.8, 82.2)	80.0 (76.0, 84.1) †
Non-Hispanic White	68.7 (67.7, 69.8)	65.2 (62.3, 68.0)	66.1 (62.8, 69.4)	67.2 (64.6, 69.9)	68.1 (65.0, 71.2)	68.7 (64.9, 72.5) †	70.6 (69.0, 72.2) †	71.5 (68.6, 74.3) †	72.2 (68.6, 75.8) ‡
Non-Hispanic Black	75.5 (74.4, 76.6)	75.8 (72.8, 78.7)	75.5 (72.0, 79.1)	73.0 (70.6, 75.4)	76.4 (73.3, 79.5)	76.2 (73.0, 79.4)	75.5 (72.2, 78.7)	75.0 (71.8, 78.1)	76.4 (73.6, 79.1)
Other race	54.1 (51.9, 56.3)	50.4 (42.2,58.6)	51.0 (40.9, 61.0)	49.2 (41.9, 56.5)	53.0 (45.8, 60.1)	47.3 (43.5, 51.1)	50.1 (44.3, 56.0)	55.8 (50.6, 61.0)	66.5 (63.1, 70.0) ‡
Education									
Less than high school	71.8 (70.4, 73.2)	66.9 (61.8, 72.0)	67.8 (64.6, 71.0)	71.3 (68.5, 74.1)	75.0 (70.9, 79.1) ‡	71.7 (67.7, 75.7)	73.7 (70.9, 76.4) †	73.8 (69.1, 78.6) †	74.7 (71.4, 78.0) ‡

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High school graduate	72.4 (71.2, 73.6)	69.5 (67.4, 71.6)	70.0 (66.3, 73.7)	69.9 (66.8, 72.9)	71.3 (68.3, 74.4)	73.1 (68.1, 78.1)	73.6 (70.5, 76.8) †	77.3 (73.4, 81.2) ‡	74.7 (71.6, 77.8) ‡
Some college or AA degree	71.9 (70.7, 73.1)	68.1 (64.8, 71.3)	70.1 (66.8, 73.4)	69.0 (66.2, 71.8)	70.2 (66.6, 73.8)	70.5 (65.8, 75.2)	74.4 (72.4, 76.5) ‡	74.7 (71.8, 77.6) ‡	76.9 (73.6, 80.1) ‡
College graduate or above	63.6 (62.0, 65.2)	60.0 (55.0, 65.0)	60.4 (55.2,65.7)	62.3 (58.1, 66.5) ‡	62.6 (57.3, 68.0)	63.8 (58.6, 69.0) ‡	63.0 (59.7, 66.2) ‡	64.5 (60.2, 68.9) ‡	69.5 (65.0, 74.0) ‡
Poverty income ratio									
< 130%	68.8 (67.4, 70.3)	62.6 (59.1, 66.1)	67.3 (63.1, 71.6) ‡	67.1 (63.9, 70.4) †	71.1 (66.3, 75.8) ‡	68.4 (64.2, 72.7) ‡	69.1 (65.9, 72.4) ‡	72.6 (68.1, 77.2) ‡	71.0 (67.1, 74.9) ‡
≥ 130%	69.9 (68.9, 70.9)	67.3 (64.8, 69.8)	67.2 (64.1, 70.4)	68.3 (66.5, 70.2)	68.8 (65.9, 71.6)	69.3 (65.6, 73.0)	71.3 (69.1, 73.6) †	71.6 (68.2, 75.0) †	74.9 (72.3, 77.4) ‡
Physical activity									
Inactive	75.6 (74.3, 76.9)	67.8 (59.4, 76.0)	74.2 (66.0, 82.6)	71.7 (69.5, 74.0)	76.3 (73.4, 79.2)	63.2 (56.5, 69.9)	78.4 (75.4, 81.5) †	77.6 (73.8, 81.4) †	78.3 (75.4, 81.2) †
Insufficiently active	69.7 (68.1, 71.3)	68.3 (66.1, 70.5)	68.2 (63.6, 72.7)	69.4 (65.9, 73.0)	68.1 (64.1, 72.1)	59.6 (53.1, 66.1) †	71.0 (66.0, 76.0)	76.0 (70.1, 81.8) †	81.1 (77.8, 84.4) ‡
Sufficiently active	67.9 (66.7, 69.1)	60.9 (56.1, 65.7)	62.0 (58.2, 65.7)	66.4 (63.9, 68.8)	66.7 (62.9, 70.4)	70.8 (67.6, 74.0) ‡	67.4 (65.4, 69.4) †	69.3 (66.3, 72.2) ‡	71.1 (67.8, 74.5) ‡
Total energy intake									
Tetile 1	70.9 (69.4, 72.3)	66.9 (63.7, 70.1)	68.1 (64.1, 72.0)	71.0 (67.4, 74.5)	69.7 (66.0, 73.3)	71.8 (66.7, 76.9)	72.9 (69.1, 76.7) ‡	73.9 (69.9, 77.9) ‡	71.7 (67.5, 75.8) ‡
Tetile 2	70.7 (69.3, 72.0)	65.0 (61.8, 68.2)	70.0 (66.3, 73.6) †	68.2 (64.2, 72.1)	70.6 (66.7, 74.6) †	71.5 (67.6, 75.3) †	73.2 (69.6, 76.8) ‡	71.1 (66.6, 75.7) †	75.4 (72.0, 78.9) ‡
Tetile 3	69.8 (68.7, 71.0)	68.4 (64.9, 71.9)	66.7 (63.0, 70.4)	68.7 (66.2, 71.3)	69.1 (65.0, 73.1)	68.2 (64.9, 71.4)	69.6 (66.9, 72.3)	73.1 (70.3, 75.8) †	75.0 (71.4, 78.5) †

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination Survey (2003–2018). († $p < 0.05$; ‡ $p < 0.01$)

Abbreviations: AA, Associate of Arts; BMI, body mass index; CI, confidence interval.

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Table S5. Change in mean BMI by sex among adults in the United States, 2003-2018

Years	Weighted mean BMI					
	Men		Women		Both	
	Adjusted β * (95%CI)	p-value	Adjusted β * (95%CI)	p-value	Adjusted β * (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	0.38 (-0.29,1.06)	0.259	0.44 (-0.47, 1.35)	0.338	0.38 (-0.23,0.99)	0.215
2007 - 2008	0.42 (-0.14,0.97)	0.139	0.52 (-0.10, 1.15)	0.102	0.48 (0.04,0.93)	0.035
2009 - 2010	0.72 (0.09,1.35)	0.025	0.64 (0.04, 1.23)	0.037	0.70 (0.26,1.15)	0.002
2011 - 2012	0.64 (0.04, 1.23)	0.035	1.50 (0.84, 2.16)	<0.001	1.08 (0.55, 1.61)	<0.001
2013 - 2014	0.73 (0.18, 1.28)	0.010	1.55 (0.78, 2.32)	<0.001	1.18 (0.66, 1.70)	<0.001
2015 - 2016	1.28 (0.62, 1.95)	<0.001	1.88 (1.15, 2.61)	<0.001	1.59 (1.03, 2.20)	<0.001
2017 - 2018	1.62 (1.00, 2.24)	<0.001	2.26 (1.30, 3.21)	<0.001	1.96 (1.34, 2.57)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: CI, confidence interval.

* Models adjusted for age, sex , race, education, family poverty income ratio, daily total energy intake and physical activity status.

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Table S6. Change in prevalence of obesity by sex among adults in the United States, 2003-2018

Years	Prevalence of obesity					
	Men		Women		Both	
	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	1.03 (0.96, 1.09)	0.402	1.04 (0.98, 1.09)	0.197	1.03 (0.99, 1.07)	0.184
2007 - 2008	1.03 (0.98, 1.08)	0.229	1.03 (0.99, 1.07)	0.193	1.03 (1.00, 1.06)	0.084
2009 - 2010	1.07 (1.02, 1.13)	0.008	1.04 (1.01, 1.08)	0.026	1.06 (1.03, 1.09)	<0.001
2011 - 2012	1.06 (1.03, 1.11)	0.028	1.08 (1.04, 1.13)	<0.001	1.07 (1.03, 1.11)	<0.001
2013 - 2014	1.06 (1.01, 1.11)	0.011	1.08 (1.05, 1.14)	<0.001	1.08 (1.04, 1.11)	<0.001
2015 - 2016	1.11 (1.04, 1.18)	<0.001	1.12 (1.07, 1.17)	<0.001	1.11 (1.07, 1.16)	<0.001
2017 - 2018	1.17 (1.09, 1.24)	<0.001	1.14 (1.08, 1.21)	<0.001	1.15 (1.10, 1.21)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: CI, confidence interval; OR, odds ratio.

Crude model: we did not adjust other covariants.

* Models adjusted for age, sex , race, education, family poverty income ratio, daily total energy intake and physical activity status.

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Table S7. Change in prevalence of overweight by sex among adults in the United States, 2003-2018

Years	Prevalence of overweight					
	Men		Women		Both	
	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value	Adjusted OR * (95%CI)	p-value
2003 - 2004	Reference		Reference		Reference	
2005 - 2006	1.01 (0.96, 1.06)	0.580	1.01 (0.95, 1.08)	0.690	1.01 (0.97, 1.05)	0.598
2007 - 2008	1.00 (0.96, 1.05)	0.868	1.03 (0.98, 1.08)	0.206	1.02 (0.98, 1.05)	0.281
2009 - 2010	1.02 (0.97, 1.08)	0.406	1.03 (0.98, 1.08)	0.248	1.03 (0.99, 1.07)	0.178
2011 - 2012	1.01 (0.96, 1.06)	0.819	1.08 (1.03, 1.14)	0.002	1.05 (1.00, 1.09)	0.034
2013 - 2014	1.02 (0.98, 1.07)	0.370	1.07 (1.02, 1.12)	0.010	1.05 (1.01, 1.08)	0.012
2015 - 2016	1.03 (0.98, 1.08)	0.305	1.09 (1.04, 1.15)	0.001	1.06 (1.02,1.10)	0.005
2017 - 2018	1.05 (1.00, 1.11)	0.050	1.11 (1.05, 1.17)	<0.001	1.08 (1.04, 1.13)	<0.001
P for trend		<0.001		<0.001		<0.001

Abbreviations: CI, confidence interval; OR, odds ratio.

* Models adjusted for age, sex , race, education, family poverty income ratio, daily total energy intake and physical activity status.

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Table S8. Characteristics of participants according to tertiles of daily total energy intake*

Characteristic	Total (n=34,625)	Daily total energy intake (Kcal/d) †			*P*-value
		Tertile1 (n=9,991)	Tertile2 (n=8,990)	Tertile3 (n=1,5644)	
Age, years	48.81 ± 0.48	49.57 ± 0.28	48.23± 0.28	46.38 ± 0.25	< 0.001
Sex, n (%)					< 0.001
Male, n (%)	16,457 (47.20)	3,159 (27.81)	4,442 (48.79)	8,856 (56.63)	
Female, n (%)	18,168 (52.80)	6,832 (72.19)	4,548 (51.21)	6,788 (43.37)	
Race, n (%)					< 0.001
Mexican American	5,430 (7.85)	1,670 (8.43)	1,383 (7.43)	2,377 (7.78)	
Other Hispanic	2,973 (5.02)	1,049 (6.46)	698 (4.33)	1,226 (4.65)	
Non-Hispanic White	15,635 (69.51)	3,905 (64.17)	4,353 (72.29)	7,377 (70.77)	
Non-Hispanic Black	7,384 (10.97)	2,465 (13.87)	1,759 (9.64)	3,160 (10.19)	
Other Race	3,203 (6.64)	902.00 (7.06)	797.00 (6.31)	1,504 (6.60)	
Education, n (%)					< 0.001
Less than high school	8,224 (14.99)	3,085 (19.78)	1,912(13.29)	3,227 (13.39)	
High school graduate	8,042 (23.55)	2,397 (25.76)	2,051 (22.95)	3,594 (22.71)	
Some college or AA degree	10,281 (31.61)	2,727 (29.98)	2,748 (32.51)	4,806 (31.98)	
College graduate or above	8,049 (29.80)	1,773 (24.41)	2,272 (31.20)	4,004 (31.88)	
Poverty income ratio, n (%)					< 0.001
< 130%	9,588 (19.89)	3,157(24.23)	2,335 (18.50)	4,096 (18.41)	
≥ 130%	22,370 (80.11)	5,931(75.77)	5,972 (81.50)	10,467 (81.59)	
BMI, kg/m^2	29.05 ±0.08	29.30±0.11	28.95 ±0.11	28.97±0.10	
BMI, kg/m^2 (group)					< 0.001
< 25	9,896 (30.04)	2,614 (29.47)	2,609 (29.83)	4,673 (30.47)	
25 - 30	11,505 (32.91)	3,245 (31.00)	3,080 (34.39)	5,180 (33.09)	
≥ 30	13,224 (37.04)	4,132 (39.53)	3,301 (35.78)	5,791 (36.44)	
Overweight					0.3
No	9,788 (29.68)	2,583 (29.14)	2,576 (29.33)	4,629 (30.16)	
Yes	24,837 (70.32)	7,408 (70.86)	6,414 (70.67)	11,015 (69.84)	
Obesity					< 0.001
No	21,294 (62.65)	5,829 (60.14)	5,660 (63.95)	9,805 (63.25)	
Yes	13,331 (37.35)	4,162 (39.86)	3,330 (36.05)	5,839 (36.75)	
Physical activity, n (%)					< 0.001
Inactive	6,677 (17.45)	2,329 (21.39)	1,681 (16.85)	2,667 (15.71)	
Insufficiently active	5,548 (17.92)	1,540 (16.56)	1,499 (18.54)	2,509 (18.29)	
Sufficiently active	19,207 (64.63)	5,127 (62.05)	5,007 (64.61)	9,073 (66.00)	

* Data are presented incorporating sample weights and adjusted for clusters and strata of the complex sample design of the National Health and Nutrition Examination

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Survey (2003-2018).

† Values are presented as mean ± SE for continuous variables and unweighted numbers (weighted %) for categorical variables.

Abbreviations: AA, Associate of Arts; BMI, body mass index

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STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2,3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6,7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6,7*
Bias	9	Describe any efforts to address potential sources of bias	6,7
Study size	10	Explain how the study size was arrived at	
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6,7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7,8
		(*b*) Describe any methods used to examine subgroups and interactions	7,8
		(*c*) Explain how missing data were addressed	7
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	7,8

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		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	8
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8,9
		(b) Indicate number of participants with missing data for each variable of interest	8,9
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	8,9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9,10,11
		(*b*) Report category boundaries when continuous variables were categorized	9,10,11
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	10,11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13,14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14
Generalisability	21	Discuss the generalisability (external validity) of the study results	14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	14,15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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