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RESEARCH ARTICLE

Prevalence and Trends in Lifetime Obesity in the U.S., 1988–2014

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Introduction: Estimates of obesity prevalence based on current BMI are an important but incomplete indicator of the total effects of obesity on a population.

Methods: In this study, data on current BMI and maximum BMI were used to estimate prevalence and trends in lifetime obesity status, defined using the categories never (maximum BMI ≤30 kg/m^2), former (maximum BMI ≥30 kg/m^2 and current BMI ≤30 kg/m^2), and current obesity (current BMI ≥30 kg/m^2). Prevalence was estimated for the period 2013–2014 and trends for the period 1988–2014 using data from the National Health and Nutrition Examination Survey. Predictors of lifetime weight status and the association between lifetime weight categories and prevalent disease status were also investigated using multivariable regression.

Results: A total of 50.8% of American males and 51.6% of American females were ever obese in 2013–2014. The prevalence of lifetime obesity exceeded the prevalence of current obesity by amounts that were greater for males and for older persons. The gap between the two prevalence values has risen over time. By 2013–2014, a total of 22.0% of individuals who were not currently obese had formerly been obese. For each of eight diseases considered, prevalence was higher among the formerly obese than among the never obese.

Conclusions: A larger fraction of the population is affected by obesity and its health consequences than is suggested in prior studies based on current BMI alone. Weight history should be incorporated into routine health surveillance of the obesity epidemic for a full accounting of the effects of obesity on the U.S. population.

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INTRODUCTION

Routine health surveillance has largely ignored weight histories in estimating prevalence and trends in obesity.[1–6] This situation contrasts with health statistics on smoking, which commonly track past and present smoking behavior, differentiating among never, former, and current smokers.[7] As in the case of smoking, histories may provide a more comprehensive picture of the burden of obesity in the population than data based on current weight status alone.[8–11]

Integrating obesity history into health surveillance would be especially important if individuals who were formerly overweight or obese and subsequently lost weight are at elevated risk of morbidity and mortality. Prior research has found that the health effects of obesity are cumulative,[12–17] implying that a member of the normal weight category who was formerly overweight or obese may be at higher risk of experiencing obesity-related health outcomes than those who have always maintained normal weight. Additionally, some people who have experienced weight loss may have done so as a

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result of age-related loss of lean muscle mass, known as sarcopenia,[18–23] or an illness, with disease-associated weight loss particularly prevalent among older ages and in certain high-risk subpopulations, such as smokers and those with a history of illness.[24–31]

The objective of this study is to integrate weight history into estimates of prevalence and trends in obesity in the U.S. adult population. The proportion of the population that was never obese versus those who were obese at some point during life is estimated using data on lifetime maximum BMI (max BMI) from the National Health and Nutrition Examination Survey (NHANES). Analyses further differentiate the ever obese group into those who were currently versus formerly obese. Predictors of membership in the different lifetime weight categories and the association between lifetime weight categories and prevalent disease status are investigated using multivariable regression.

METHODS

Study Sample

Prevalence and trends in lifetime obesity status were investigated using data from the 1988–1994 and 1999–2014 waves of NHANES.[32,33] NHANES is a nationally representative survey of the civilian non-institutionalized population of the U.S. The survey was carried out periodically until 1999, when it became a continuous survey released in 2-year intervals. Participants were interviewed for basic demographic and health information at home, and their physical examinations and laboratory testing were completed by trained technicians at a mobile examination center.

Several exclusion criteria were adopted for the analyses. The sample was restricted to adults aged ≥20 years with non-missing data on lifetime maximum weight, weight and height at survey, and other covariates included in the analysis. Women who were pregnant at the time of the exam were also excluded. The final sample size combining all waves of data was 52,819.

Measures

Information on lifetime maximum weight, a key independent variable in this study, was obtained from a question that asks respondents to recall their maximum lifetime weight, excluding weight during pregnancy for women. Maximum weight was combined with height measured at survey to construct lifetime max BMI. BMI at the time of the exam (current BMI) was calculated using data on measured height and weight. Sociodemographic variables, smoking status, and prevalent disease status were determined by interview. Information on prevalent conditions was obtained through a series of questions that asked respondents if they had ever received a diagnosis of the given condition from a doctor or other health professional.

Obesity was defined as a BMI of ≥30.0 kg/m^2, according to guidelines from the National Heart, Lung, and Blood Institute.[34] Individuals were categorized as never versus ever obese based on whether their lifetime max BMI exceeded 30.0 kg/m^2. The ever obese category was further disaggregated into those who were currently obese versus those who were formerly obese. An individual was defined as currently obese if they had a BMI at survey of ≥30.0 kg/m^2. Former obesity was defined as a lifetime max BMI of ≥30.0 kg/m^2, but current BMI <30.0 kg/m^2. Participant age was classified into three categories: 20–39, 40–59, and ≥60 years. Race/ethnicity was grouped into categories of non-Hispanic white, non-Hispanic black, Hispanic, and other. Self-reported education level was grouped into the categories less than high school, high school graduate, and more than high school. Smoking status was defined using the categories never, former, and current smoker.

Statistical Analysis

The age-standardized prevalence of lifetime obesity was calculated using data from the latest 2-year cycle of the continuous NHANES survey (2013–2014). Age-standardization was performed using the direct method to the 2000 U.S. Census population using the following age groups: 20–29, 30–39, 40–49, 50–59, 60–69, 70–79, and ≥80 years. Multivariable logistic models were estimated to evaluate associations between age, race/ethnicity, education, and smoking status and the likelihood of being currently or ever obese. The models were implemented separately by sex as a preliminary analysis revealed that sex was a significant effect modifier of the association between race/ethnicity and obesity status.

Using the never obese group as the reference, the prevalence of several obesity-related diseases was investigated. The multivariable logistic models were adjusted for age, race/ethnicity, educational level, and smoking status and stratified by gender. Data from 1999–2014 were pooled to examine the association between obesity and disease prevalence. Data from 1988–2014 were used to describe obesity trends across the decades. The Cochran–Armitage test was performed to test the trend in prevalence of ever and current obesity across survey years and categories of age.

Because individuals may lose height as they age, an alternative measure of max BMI adjusting for age-related height loss between age at max weight and current age was investigated in a sensitivity analysis pooling data from 1999–2014 (Appendix, available online). Data analyses were performed using SAS, version 9.4. All estimates were adjusted for the complex survey design of the NHANES, and a 2-tailed p-value of ≤0.05 was applied to determine statistical significance.

RESULTS

Table 1 shows the proportion of people who were never obese and those who were ever obese in 2013–2014 according to sex, age, and race/ethnicity. The ever-obese category is disaggregated into those who are currently obese and those who were formerly obese. The table shows that obesity has affected about half of adult males (50.8%) and females (51.6%). Among those who have ever been obese, males were more likely to have exited the category: 30.3% of men who were once obese are no longer so (15.4/50.8), compared with 23.6% of women (12.2/51.6). The common transitions from currently obese to formerly obese mean that a high proportion of those who were not obese at survey had previously been obese: 23.8% among men (15.4/(15.4 + 49.2)) and 20.1% among women (12.2/(12.2 + 48.4)).

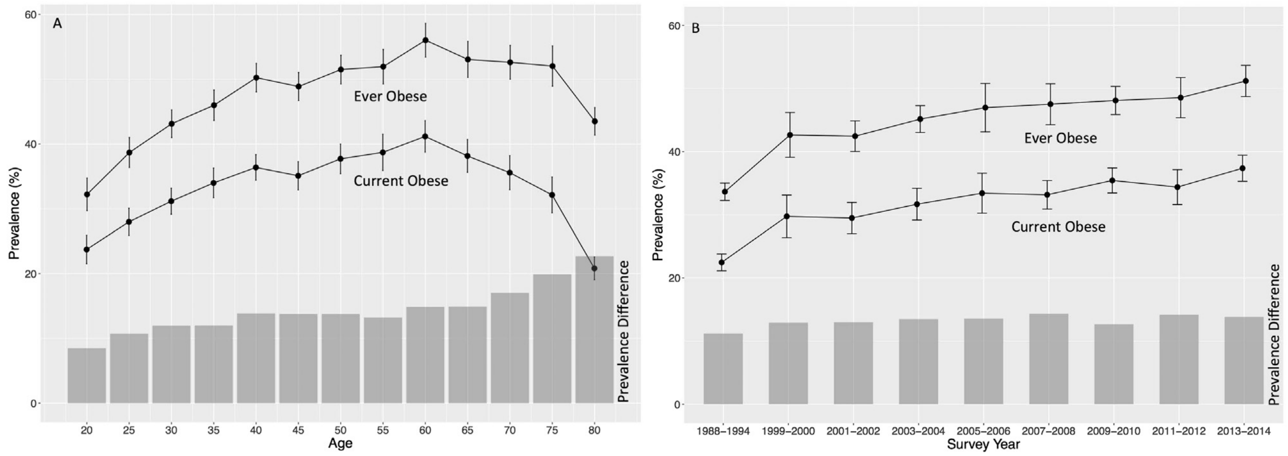

Figure 1. Obesity status of U.S. adults by (A) age and (B) calendar year.
Note: Prevalence estimates by calendar year are age-standardized to the U.S. population in 2000. Sources: (A) NHANES 1999–2014; (B) NHANES 1988–2014.
NHANES, National Health and Nutrition Examination Survey.

The percentage of people who have ever been obese and the percentage who are currently obese peaked in the age range of 55–69 years, as shown in Figure 1A. At higher ages, the proportion currently obese fell off more rapidly with age than the lifetime prevalence of obesity, so that by age ≥80 years there were more people who were formerly obese than currently obese.

Racial and ethnic differences in weight histories are striking, particularly among women. Of non-Hispanic white women, 51.0% were never obese, compared to only 30.4% of black women (Table 1). Hispanic women were roughly halfway between the two, whereas the "other" category, primarily Asian Americans, showed by far the highest frequency of having never been obese at 69.0%. Not only were black women more likely to have been obese than white women, but their obesity was more persistent: 19.3% of black women who have ever been obese have exited the status (13.4/69.6), compared to 25.1% of white women (12.3/49.0).

Table 2 presents the results of a multivariable model predicting lifetime and current obesity status for this population. Using either outcome variable, results were similar for race/ethnicity and for educational attainment. Controlling other variables in the model, blacks and Hispanics were much more likely to be obese than whites; the racial differential was especially large for black versus white women. Compared to white men, black men were also significantly more likely to be currently obese or to have ever been obese, but the racial differential was much smaller than among women. Women who attended college were at lower risk of obesity, current or lifetime, than women who did not finish high school. A reduction in risk associated with higher educational attainment was not observed in men. Thus, women show a far more variegated pattern of racial/ethnic and educational differentials in current or lifetime obesity than men.

Patterns of current and lifetime obesity diverged when attention turned to age or smoking status. Consistent with Table 1, Table 2 shows that persons aged ≥60 years had a much higher risk of lifetime obesity than of current obesity. That pattern is evident for both men and women. Controlling other variables in the model, the prevalence of lifetime obesity increased between groups aged 40–59 and ≥60 years while the prevalence of current obesity declined between these ages.

Table 2 also shows that current smokers were less likely to be obese than never smokers. However, current smokers were more likely to have been obese in their lifetimes than never smokers (OR=1.25 for females, OR=1.10 for males). People who formerly smoked were much more likely to have been obese than people who never smoked. Among males, former smokers had odds of lifetime obesity that were 81% greater than those of never smokers, whereas their odds of being currently obese were only 27% higher.

Figure 1B shows the time-trend in the age-standardized prevalence of current and lifetime obesity among American adults. The data series extends from 1988–1994 to 2013–2014. The proportion currently obese rose steadily over this period from 22.5% to 37.4%, while the proportion ever-obese increased from 33.7% to 51.2%. By 2013–2014, over half of American adults had been obese at some point during their lifetime.

The difference between these two series is the proportion formerly obese. That proportion rose from 11.2% in 1988 to 13.8% in 2014. The formerly obese represent a rapidly rising fraction of those who are non-obese. Among those who were not obese in 1988, 14.4% were formerly obese, whereas in 2014, 22.0% were formerly

Table 1. Age-standardized Prevalence of Never, Former, Current, and Ever Obese for Adults Aged ≥20 Years in the NHANES 2013–2014

	Weight status % (95% CI)			
Characteristic	**Never obese**	**Former obese**	**Current obese**	**Ever obese**
Total				
N	2,521	778	1,992	2,770
Age-standardized prevalence	48.8 (46.3, 51.3)	13.8 (12.3, 15.3)	37.4 (35.3, 39.4)	51.2 (48.7, 53.7)
Age, years				
20–39	54.4 (50.7, 58.1)	11.8 (10.0, 13.5)	33.8 (30.7, 37.0)	45.6 (41.9, 49.3)
40–59	46.6 (42.4, 50.8)	12.9 (10.5, 15.2)	40.5 (36.2, 44.9)	53.4 (49.2, 57.6)
≥60	43.4 (39.7, 47.1)	17.9 (15.0, 20.9)	38.7 (35.3, 42.1)	56.6 (52.9, 60.3)
Race/ethnicity				
Non-Hispanic white	53.0 (47.4, 53.2)	13.9 (12.2, 15.6)	35.8 (33.1, 38.5)	49.7 (46.8, 52.6)
Non-Hispanic black	38.2 (34.2, 42.2)	14.0 (10.7, 17.3)	47.8 (43.5, 52.1)	61.8 (57.8, 65.8)
Hispanic	39.4 (34.8, 44.0)	16.7 (13.1, 20.3)	43.9 (39.5, 48.3)	60.6 (56.0, 65.2)
Other	69.9 (63.9, 75.8)	9.5 (6.2, 12.8)	20.6 (16.1, 25.1)	30.2 (24.2, 36.1)
Female				
N	1,231	346	1,130	1,476
Age-standardized prevalence	48.4 (45.6, 51.3)	12.2 (10.3, 14.0)	39.4 (36.6, 42.2)	51.6 (48.7, 54.4)
Age, years				
20–39	53.5 (49.9, 57.1)	10.5 (8.3, 12.8)	36.0 (33.5, 38.4)	46.5 (42.9, 50.1)
40–59	45.9 (41.0, 50.8)	10.5 (7.2, 13.8)	43.6 (38.1, 49.2)	54.1 (49.2, 59.0)
≥60	43.7 (40.1, 47.3)	16.9 (12.8, 21.0)	39.4 (35.4, 43.5)	56.3 (52.7, 59.9)
Race/ethnicity				
Non-Hispanic white	51.0 (48.3, 53.7)	12.3 (10.3, 14.3)	36.7 (33.2, 40.3)	49.0 (46.3, 51.7)
Non-Hispanic black	30.4 (26.1, 34.8)	13.4 (10.3, 16.5)	56.2 (52.6, 59.7)	69.6 (65.2, 73.9)
Hispanic	39.9 (34.5, 45.3)	12.6 (8.2, 17.1)	47.4 (42.6, 42.3)	60.1 (54.7, 65.5)
Other	69.0 (60.2, 77.8)	11.4 (6.7, 16.1)	19.6 (13.1, 26.0)	31.0 (22.2, 39.8)
Male				
N	1,290	432	862	1,294
Age-standardized prevalence	49.2 (46.3, 52.1)	15.4 (13.5, 17.4)	35.3 (33.1, 37.6)	50.8 (47.9, 53.7)
Age, years				
20–39	55.2 (50.1, 60.4)	12.9 (10.6, 15.3)	31.8 (27.1, 36.6)	44.8 (39.6, 49.9)
40–59	47.4 (42.3, 52.4)	15.3 (11.7, 18.9)	37.3 (32.2, 42.5)	52.6 (47.6, 57.7)
≥60	43.0 (36.6, 49.4)	19.2 (16.1, 22.3)	37.8 (31.3, 44.2)	57.0 (50.6, 63.4)
Race/ethnicity				
Non-Hispanic white	49.5 (45.6, 53.5)	15.5 (12.8, 18.2)	35.0 (31.5, 38.4)	50.5 (46.5, 54.2)
Non-Hispanic black	47.3 (42.1, 52.5)	14.8 (10.3, 19.3)	37.9 (32.2, 43.7)	52.7 (47.5, 57.9)
Hispanic	39.8 (32.9, 46.7)	20.5 (17.0, 23.9)	39.8 (33.2, 46.3)	60.2 (53.3, 67.1)
Other	72.0 (65.2, 78.8)	7.4 (3.8, 11.1)	21.0 (15.2, 26.0)	28.0 (21.2, 34.8)

Note: Age-adjusted estimates were adjusted by the direct method to the 2000 U.S. Census population using age groups in 10-year intervals (20–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, 70–79 years, ≥80 years). Ever obese is the sum of former and current obese. NHANES, National Health and Nutrition Examination Survey.

obese. The results from the Cochran–Armitage tests for trends indicate that both ordinal survey years and age levels were positively associated with being current or ever obese (p-trend from all four tests <0.0001).

One approach to minimizing the bias from the presence of the formerly obese among the currently non-obese is to use the group of people who have never been obese as the reference category.[9,10] Table 3 demonstrates the value of this approach by using a logistic regression model to compare the prevalence of various diseases across three categories of weight status: never obese, formerly obese, and currently obese.

For each of the eight diseases for both sexes, the OR was higher among the formerly obese than among the never obese. In 15 of the 16 contrasts, the higher disease prevalence among the formerly obese was statistically significant ($p<0.05$). Table 3 also shows that, with two exceptions, the odds of having been diagnosed with a disease for those who were formerly obese lie between the odds for the currently obese and those for the never obese.

Table 2. Multivariable Logistic Regression Models of Weight Status, Adjusting for Race/Hispanic Origin, Age Group, Smoking Status, and Education in the NHANES 2013–2014

	Weight status OR (95% CI)			
	Female		Male	
Characteristic	Current obese	Ever obese	Current obese	Ever obese
Age, years				
20–39	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
40–59	1.38 (1.10, 1.74)	1.35 (1.06, 1.72)	1.27 (0.90, 1.78)	1.38 (1.06, 1.79)
≥60	1.10 (0.88, 1.38)	1.49 (1.18, 1.77)	1.17 (0.72, 1.90)	1.46 (0.96, 2.22)
Race/ethnicity				
Non-Hispanic white	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Non-Hispanic black	2.16 (1.80, 2.60)	2.44 (2.03, 2.93)	1.23 (0.89, 1.68)	1.19 (0.93, 1.51)
Hispanic	1.41 (1.02, 1.94)	1.49 (1.14, 1.94)	1.26 (0.86, 1.86)	1.60 (1.11, 2.32)
Other	0.42 (0.27, 0.63)	0.49 (0.32, 0.73)	0.55 (0.36, 0.84)	0.43 (0.29, 0.64)
Education				
<High school	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
High school	1.04 (0.76, 1.42)	1.15 (0.85, 1.55)	1.07 (0.74, 1.53)	1.22 (0.88, 1.69)
>High school	0.73 (0.57, 0.95)	0.80 (0.58, 1.11)	1.01 (0.68, 1.50)	1.04 (0.73, 1.48)
Smoking status				
Never	1 (Ref)	1 (Ref)	1 (Ref)	1 (Ref)
Former	1.29 (0.96, 1.75)	1.43 (1.08, 1.90)	1.27 (0.94, 1.71)	1.81 (1.37, 2.38)
Current	0.99 (0.61, 1.59)	1.25 (0.80, 1.94)	0.73 (0.55, 0.96)	1.10 (0.93, 1.29)

Note: Multivariable models adjusted for age categories, race/ethnicity, educational levels, and smoking status. “Current obese” column uses non-obese as the comparison, and “Ever obese” uses never obese as the comparison.
NHANES, National Health and Nutrition Examination Survey.

The proportion ever obese represented 47.0% of the population before adjustment for age-related height loss and 46.3% after adjustment in a pooled sample combining data from 1999–2014 (Appendix Table 1, available online). Equivalent figures for women were 46.1% and 45.0%; for men, they were 48.0% and 47.5%. Limiting the sample to ages above which height loss begins, the ever obese represented 55.3% of the population before adjustment and 52.5% after adjustment (Appendix Table 2, available online).

DISCUSSION

Incorporating data on lifetime weight status indicates that slightly more than half of the U.S. adult population has been obese at some point in their lifetime, pointing to a greater burden of obesity than is indicated in prior studies based on current weight status alone.[1–6] The gap between current obesity and lifetime obesity widened at older ages, with the proportion of the population in the formerly obese category surpassing the proportion currently obese at ages ≥80 years. The gap also increased over time, such that a greater proportion of the non-obese population in 2013–2014 was formerly obese compared to the corresponding proportion in 1988–1994. An investigation of the association between lifetime weight status and prevalent disease further revealed that those with a history of obesity had a higher prevalence of each of the eight diseases examined compared to those who had never been obese. The finding that, among non-obese individuals, those with a history of obesity have a higher prevalence of disease highlights the importance of separately considering this subpopulation in population monitoring of the obesity epidemic.

The higher risks of disease in the formerly obese compared to the never obese population may be produced by several factors. First, if the effects of obesity are cumulative, as prior studies have suggested, there may be a residual influence of past obesity that persists after voluntary weight loss.[12–17] Second, the formerly obese category may include individuals suffering from sarcopenia, a common feature of aging. These individuals have reduced skeletal muscle mass, sometimes combined with increased central adiposity. Several studies have found sarcopenia and sarcopenic obesity to be associated with elevated risks of metabolic disease and mortality.[18–23] Finally, the former obese category may also include individuals who have lost weight due to an illness.[24–31]

Identifying the relative importance of these mechanisms is beyond the scope of the current study, and prospective cohort data with information on incident disease status would be better suited for identifying

Table 3. Multivariable Logistic Models of Obesity-related Diseases by Weight Status in NHANES 1999–2014

	Weight categories					
	Never obese (N=19,045)		Former obese (N=5,525)		Current obese (N=13,202)	
Disease	*n* (%)	OR (95% CI)	*n* (%)	OR (95% CI)	*n* (%)	OR (95% CI)
Female						
Diabetes	519 (3.69)	1 (Ref)	433 (15.43)	3.87 (3.23, 4.64)	1,525 (17.38)	5.61 (4.76, 6.61)
CHF	138 (1.15)	1 (Ref)	122 (3.94)	2.35 (1.71, 3.23)	273 (3.31)	2.86 (2.15, 3.81)
CHD	194 (1.66)	1 (Ref)	99 (3.68)	1.60 (1.15, 2.24)	218 (2.71)	1.75 (1.37, 2.23)
Angina	152 (1.38)	1 (Ref)	97 (3.53)	1.88 (1.31, 2.69)	259 (3.23)	2.42 (1.87, 3.12)
Heart attack	190 (1.70)	1 (Ref)	99 (3.65)	1.52 (1.10, 2.11)	265 (3.21)	1.96 (1.53, 2.50)
Stroke	244 (2.14)	1 (Ref)	141 (5.19)	1.78 (1.34, 2.35)	303 (3.57)	1.66 (1.29, 2.13)
Arthritis	2,198 (21.67)	1 (Ref)	881 (35.78)	1.58 (1.37, 1.82)	2,856 (37.30)	2.33 (2.13, 2.56)
Liver disease	233 (2.25)	1 (Ref)	89 (3.68)	1.50 (1.08, 2.08)	273 (3.51)	1.62 (1.27, 2.06)
Male						
Diabetes	667 (4.87)	1 (Ref)	652 (12.86)	2.50 (2.10, 2.97)	1,222 (16.52)	4.06 (3.48, 4.74)
CHF	216 (1.50)	1 (Ref)	151 (3.39)	1.73 (1.31, 2.27)	304 (3.55)	2.48 (1.94, 3.18)
CHD	406 (3.21)	1 (Ref)	250 (6.11)	1.44 (1.12, 1.84)	418 (5.99)	1.92 (1.59, 2.33)
Angina	234 (1.93)	1 (Ref)	137 (3.26)	1.27 (0.97, 1.67)	265 (3.86)	2.01 (1.63, 2.48)
Heart attack	390 (2.86)	1 (Ref)	274 (6.28)	1.71 (1.35, 2.18)	438 (5.83)	2.15 (1.79, 2.58)
Stroke	244 (1.55)	1 (Ref)	175 (3.36)	1.69 (1.29, 2.21)	258 (2.91)	1.94 (1.57, 2.40)
Arthritis	1,563 (14.21)	1 (Ref)	956 (25.11)	1.64 (1.43, 1.88)	1,688 (26.03)	2.10 (1.89, 2.34)
Liver disease	313 (2.98)	1 (Ref)	179 (4.85)	1.50 (1.15, 1.96)	254 (4.11)	1.39 (1.07, 1.80)

Note: Adjusted for race/ethnicity, age at survey, educational level, and smoking status. Individuals reporting "borderline" diabetes were included in the definition of diabetes. The counts of the subjects in each category are unweighted, but the prevalence values are weighted.
Angina, angina/angina pectoris; CHD, coronary heart disease; CHF, congestive heart failure; NHANES, National Health and Nutrition Examination Survey.

causality. However, it is worth noting that the lower estimated risks of prevalent disease among the formerly obese than among the currently obese is consistent with studies on the health benefits of voluntary weight loss.[35–39] The results are also consistent with obesity representing a cumulative health burden over the life course, given that disease prevalence was higher among the formerly obese than among the never obese. Yet given the limited efficacy of lifestyle interventions and pharmacologic therapies for weight loss,[40] combined with the low uptake of bariatric surgery to date in the U.S.,[41–43] it is likely that the formerly obese category identified in this study includes at least some individuals with aging- and illness-related weight loss.

The estimates generated in this study have implications for studies examining the health risks associated with obesity status. If the formerly-obese group is included in one omnibus "non-obese" category, as it is in much of the literature on obesity and health status,[44–50] it would understate the advantages of avoiding obesity altogether. Prior research has shown that failing to account for weight history may have substantially underestimated the effects of obesity on mortality.[9–11] The current study may also help to explain why paradoxical associations between obesity and mortality commonly emerge in older as compared to younger adult populations.[47,51–53] The results indicate that the prevalence of former obesity increased with age, such that the inclusion of former obese individuals in the non-obese category would pose more of a threat to obtaining unbiased estimates of the obesity–mortality association at older ages. Likewise, the increasing prevalence of former obesity over time, which may be expected to accelerate as new therapies for obesity are developed, may help to explain the finding in several prior studies that the mortality risks of obesity have declined over time.[54–57] Instead of representing a true decline, it may be that the reduced risks reflect the greater proportion of former obese people in the non-obese category in more recent cohorts.

The findings from this study also have implications for the way that obesity is treated in studies of other health risks. For example, in analyses of the health risks of smoking, it is desirable to expand the characterization of obesity to include obesity histories where possible. Relative to never smokers, current and former smokers are more likely to have been previously obese than they are to be currently obese (Table 2). Some of the hazards of smoking may be exaggerated if the high prevalence of former obesity among smokers is not recognized.

Limitations

A limitation of the study was that maximum weight was self-reported. A recent validation study comparing recalled max weight to self-reported weight assessed longitudinally found a high level of concordance between the two measures[58]; however, this study only assessed validity over a 12-year period prior to recall and thus the opportunity for bias over longer recall periods remains. Because people are more likely to underreport their weight than to overreport it,[59] it is possible that a higher proportion of the population was formerly obese than is indicated in this paper. When asked to recall their weight about 10 years earlier, women were more likely to underestimate their weight than men, and black women more than white women.[60] Thus, some of the differences by sex and race shown in Tables 1 and 2 may reflect misreporting of recalled maximum weight.

A second limitation of the study was that max BMI was calculated using current height rather than height at maximum weight. It is possible that current height is less than height at maximum weight because of height loss with age, thus artificially inflating the max BMI.[61] However, in a sensitivity analysis correcting for age-related height loss, the results were similar, suggesting that height loss with age was not a major source of bias in this study's estimates of lifetime obesity prevalence.

CONCLUSIONS

The population burden of obesity is larger than indicated by data on current BMI alone. In total, half of the U.S. adult population has been affected by obesity in their lifetime compared to the 37% who are obese based on current weight status. The formerly obese population, which accounts for the gap between these two estimates, is an important and growing minority of the population with elevated disease risks. It should be distinguished from never obese individuals in routine health surveillance for a full accounting of the effects of obesity on the U.S. population.

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2017.06.008.

REFERENCES

1. Flegal KM, Kruszon-Moran D, Carroll MD, et al. Trends in obesity among adults in the United States, 2005 to 2014. *JAMA*. 2016;315(21):2284–2291. https://doi.org/10.1001/jama.2016.6458.
2. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of body mass index among U.S. adults, 1999–2010. *JAMA*. 2012;307(5):491–497. https://doi.org/10.1001/jama.2012.39.
3. Flegal KM, Carroll MD, Ogden CL, Johnson C. Prevalence and trends in obesity among U.S. adults, 1999–2000. *JAMA*. 2002;288(14):1723–1727. https://doi.org/10.1001/jama.288.14.1723.
4. Flegal KM, Carroll MD, Kuczmarski RJ, Johnson CL. Overweight and obesity in the United States: prevalence and trends, 1960–1994. *Int J Obes*. 1998;22(1):39–47. https://doi.org/10.1038/sj.ijo.0800541.
5. Hedly AA, Ogen CL, Johnson CL, Carroll MD, Curtin LR, Flegal KM. Prevalence of overweight and obesity among U.S. children, adolescents, and adults. *JAMA*. 2004;291(23):2847–2850. https://doi.org/10.1001/jama.291.23.2847.
6. Committee on Evaluating Approaches to Assessing Prevalence and Trends in Obesity. *Assessing Prevalence and Trends in Obesity: Navigating the Evidence*. Washington, DC: National Academies Press; 2016. https://doi.org/10.17226/23505.
7. U.S. DHHS. *The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General*. Atlanta, GA: U.S. DHHS, 2014.
8. Preston SH, Mehta NK, Stokes A. Modeling obesity histories in cohort analyses of health and mortality. *Epidemiology*. 2013;24(1):158–166. https://doi.org/10.1097/EDE.0b013e3182770217.
9. Stokes A. Using maximum weight to redefine body mass index categories in studies of the mortality risks of obesity. *Popul Health Metr*. 2014;12:6. https://doi.org/10.1186/1478-7954-12-6.
10. Stokes A, Preston SH. Revealing the burden of obesity using weight histories. *Proc Natl Acad Sci*. 2016;113(3):572–577. https://doi.org/10.1073/pnas.1515472113.
11. Yu E, Ley SH, Manson JE, et al. Weight history and all-cause and cause-specific mortality in three prospective cohort studies. *Ann Intern Med*. 2017;166(9):613–620. https://doi.org/10.7326/M16-1390.
12. Abdullah A, Wolfe R, Stoelwinder JU, et al. The number of years lived with obesity and the risk of all-cause and cause-specific mortality. *Int J Epidemiol*. 2011;40(4):985–996. https://doi.org/10.1093/ije/dyr018.
13. Arnold M, Jiang L, Stefanick ML, et al. Duration of adulthood overweight, obesity, and cancer risk in the Women's Health Initiative: a longitudinal study from the United States. *PLoS Med*. 2016;13(8): e1002081. https://doi.org/10.1371/journal.pmed.1002081.
14. Hirko KA, Kantor ED, Cohen SS, Blot WJ, Stampfer MJ, Signorello LB. Body mass index in young adulthood, obesity trajectory, and premature mortality. *Am J Epidemiol*. 2015;182(5):441–450. https://doi.org/10.1093/aje/kwv084.
15. Reis JP, Allen N, Gibbs BB, et al. Association of the degree of adiposity and duration of obesity with measures of cardiac structure and function: the CARDIA study. *Obesity (Silver Spring)*. 2014;22(11): 2434–2440. https://doi.org/10.1002/oby.20865.
16. Reis JP, Hankinson AL, Loria CM, et al. Duration of abdominal obesity beginning in young adulthood and incident diabetes through middle age: the CARDIA study. *Diabetes Care*. 2013;36(8):1241–1247. https://doi.org/10.2337/dc12-1714.
17. Wong E, Tanamas SK, Wolfe R, et al. The role of obesity duration on the association between obesity and risk of physical disability. *Obesity (Silver Spring)*. 2015;23(2):443–447. https://doi.org/10.1002/oby.20936.

18. Batsis JA, Mackenzie TA, Lopez-Jimenez F, Bartels SJ. Sarcopenia, sarcopenic obesity, and functional impairments in older adults: National Health and Nutrition Examination Surveys 1999-2004. *Nutr Res*. 2015;35(12):1031–1039. https://doi.org/10.1016/j.nutres.2015.09.003.
19. Kohara K. Sarcopenic obesity in aging population: current status and future directions for research. *Endocrine*. 2014;45(1):15–25. https://doi.org/10.1007/s12020-013-9992-0.
20. Prado CMM, Wells JCK, Smith SR, Stephan BCM, Siervo M. Sarcopenic obesity: a critical appraisal of the current evidence. *Clin Nutr*. 2012;31(5):583–601. https://doi.org/10.1016/j.clnu.2012.06.010.
21. Stenholm S, Harris T, Rantenen T, Visser M, Kritchevsky SB, Ferrucci L. Sarcopenic obesity–definition, etiology and consequences. *Curr Opin Clin Nutr Metab Care*. 2008;11(6):693–700. https://doi.org/10.1097/MCO.0b013e328312c37d.
22. Visser M, Harris TB. Body composition and aging. In: Newman AB, Cauley JA, eds. *The Epidemiology of Aging*. New York: Springer, 2012:275–292. https://doi.org/10.1007/978-94-007-5061-6.
23. Wannamethee SG, Atkins JL. Muscle loss and obesity: the health implications of sarcopenia and sarcopenic obesity. *Proc Nutr Soc*. 2015;74(4):405–412. https://doi.org/10.1017/S002966511500169X.
24. Albanese E, Strand BH, Guralnik JM, Patel KV, Kuh D, Hardy R. Weight loss and premature death: the 1946 British birth cohort study. *PLoS One*. 2014;9(1):e86282. https://doi.org/10.1371/journal.pone.0086282.
25. Alley DE, Metter EJ, Griswold ME, et al. Changes in weight at the end of life: characterizing weight loss by time to death in a cohort study of older men. *Am J Epidemiol*. 2010;172(5):558–565. https://doi.org/10.1093/aje/kwq168.
26. Carslake D, Jeffreys M, Davey Smith G. Being overweight in early adulthood is associated with increased mortality in middle age. *Sci Rep*. 2016;6:36046. https://doi.org/10.1038/srep36046.
27. Coffey CS, Gadbury GL, Fontaine KR, Wang C, Weindruch R, Allison DB. The effects of intentional weight loss as a latent variable problem. *Stat Med*. 2005;24(6):941–954. https://doi.org/10.1002/sim.1964.
28. Joshy G, Korda RJ, Bauman A, Van Der Ploeg HP, Chey T, Banks E. Investigation of methodological factors potentially underlying the apparently paradoxical findings on body mass index and all-cause mortality. *PLoS One*. 2014;9:e88641. https://doi.org/10.1371/journal.pone.0088641.
29. Lawlor DA, Hart CL, Hole DJ, Smith GD. Reverse causality and confounding and the associations of overweight and obesity with mortality. *Obesity (Silver Spring)*. 2006;14(12):2294–2304. https://doi.org/10.1038/oby.2006.269.
30. Stokes A, Preston SH. How dangerous is obesity? Issues in measurement and interpretation. *Popul Dev Rev*. 2016;42(4):595–614. https://doi.org/10.1111/padr.12015.
31. Stokes A, Preston SH. Smoking and reverse causation create an obesity paradox in cardiovascular disease. *Obesity (Silver Spring)*. 2015;23(12): 2485–2490. https://doi.org/10.1002/oby.21239.
32. National Center for Health Statistics. Plan and operation of the third National Health and Nutrition Examination Survey, 1988–94. *Vital Health Stat 1*. 1994;32:1–407.
33. Zipf G, Chiappa M, Porter KS, Ostchega Y, Lewis BG, Dostal J. National Center for Health Statistics. National Health and Nutrition Examination Survey: plan and operations, 1999–2010. *Vital Health Stat 1*. 2010;56:1–37.
34. National Heart, Lung and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults: the evidence report. *Am J Clin Nutr*. 1998;68(4):899–917.
35. Adams TD, Davidson LE, Litwin SE, et al. Health benefits of gastric bypass surgery after 6 years. *JAMA*. 2012;308(11):1122–1131. https://doi.org/10.1001/2012.jama.11164.
36. Booth H, Khan O, Prevost T, et al. Incidence of type 2 diabetes after bariatric surgery: population-based matched cohort study. *Lancet Diabetes Endocrinol*. 2014;2(12):963–968. https://doi.org/10.1016/S2213-8587(14)70214-1.
37. Schauer PR, Bhatt DL, Kirwan JP, et al. Bariatric surgery versus intensive medical therapy for diabetes—3-year outcomes. *N Engl J Med*. 2014;370(21):2002–2013. https://doi.org/10.1056/NEJMoa1401329.
38. Sjöström L, Peltonen M, Jacobson P, et al. Association of bariatric surgery with long-term remission of type 2 diabetes and with microvascular and macrovascular complications. *JAMA*. 2014;311(22):2297–2304. https://doi.org/10.1001/jama.2014.5988.
39. Kritchevsky SB, Beavers KM, Miller ME, et al. Intentional weight loss and all-cause mortality: a meta-analysis of randomized clinical trials. *PLoS One*. 2015;10(3):e0121993. https://doi.org/10.1371/journal.pone.0121993.
40. Bray GA, Ryan DH. Update on obesity pharmacotherapy. *Ann N Y Acad Sci*. 2014;1311(1):1–13. https://doi.org/10.1111/nyas.12328.
41. American Society for Metabolic and Bariatric Surgery. Estimate of Bariatric Surgery Numbers, 2011-2015. 2016. https://asmbs.org/resources/estimate-of-bariatric-surgery-numbers. Accessed January 1, 2017.
42. Johnson E, Simpson A, Harvey J, Lockett M, Byrne K, Simpson K. Trends in bariatric surgery, 2002–2012: do changes parallel the obesity trend? *Surg Obes Relat Dis*. 2016;12(2):398–404. https://doi.org/10.1016/j.soard.2015.07.009.
43. Khan S, Rock K, Baskara A, Qu W, Nazzal M, Ortiz J. Trends in bariatric surgery from 2008 to 2012. *Am J Surg*. 2016;211(6):1041–1046. https://doi.org/10.1016/j.amjsurg.2015.10.012.
44. Abdullah A, Amin FA, Stoelwinder J, et al. Estimating the risk of cardiovascular disease using an obese-years metric. *BMJ Open*. 2014; 4(9):e005629. https://doi.org/10.1136/bmjopen-2014-005629.
45. Flegal KM, Graubard BI, Williamson DF, Gail MH. Excess deaths associated with underweight, overweight, and obesity. *JAMA*. 2005;293(15):1861–1867. https://doi.org/10.1001/jama.293.15.1861.
46. Flegal KM, Kit BK, Orpana H, Graubard BI. Association of all-cause mortality with overweight and obesity using standard body mass index categories: a systematic review and meta-analysis. *JAMA*. 2013;309(1): 71–82. https://doi.org/10.1001/jama.2012.113905.
47. Aune D, Sen A, Prasad M, et al. BMI and all cause mortality: systematic review and non-linear dose-response meta-analysis of 230 cohort studies with 3.74 million deaths among 30.3 million participants. *BMJ*. 2016;353:i2156. https://doi.org/10.1136/bmj.i2156.
48. Berrington de Gonzalez A, Hartge P, Cerhan JR, et al. Body-mass index and mortality among 1.46 million white adults. *N Engl J Med*. 2010;363:2211–2219. https://doi.org/10.1056/NEJMoa1000367.
49. The Global BMI Mortality Collaboration. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. *Lancet*. 2016;388(10046):776–786. https://doi.org/10.1016/S0140-6736(16)30175-1.
50. Whitlock G, Lewington S, Sherliker P, et al. Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. *Lancet*. 2009;373(9669):1083–1096. https://doi.org/10.1016/S0140-6736(09)60318-4.
51. Janssen I, Mark AE. Elevated body mass index and mortality risk in the elderly. *Obes Rev*. 2007;8(17):41–59. https://doi.org/10.1111/j.1467-789X.2006.00248.x.
52. Peters R, Mayer B, Concin H, Nagel G. The effect of age on the shape of the BMI–mortality relation and BMI associated with minimum all-cause mortality in a large Austrian cohort. *Int J Obes*. 2015;39(3): 530–534. https://doi.org/10.1038/ijo.2014.168.
53. Winter J, MacInnis R, Wattanapenpaiboon N, Nowson C. BMI and all-cause mortality in older adults: a meta-analysis. *Am J Clin Nutr*. 2014;99(4):875–890. https://doi.org/10.3945/ajcn.113.068122.
54. Afzal S, Tybjaerg-Hansen A, Jensen GB, Nordestgaard BG. Change in body mass index associated with lowest mortality in Denmark, 1976–2013. *JAMA*. 2016;315(18):1989–1996. https://doi.org/10.1001/jama.2016.4666.
55. Mehta NK, Chang VW. Secular declines in the association between obesity and mortality in the United States. *Popul Dev Rev*. 2014;37(3): 435–451. https://doi.org/10.1111/j.1728-4457.2011.00429.x.

56. Mehta T, Fontaine KR, Keith SW, et al. Obesity and mortality: Are the risks declining? Evidence from multiple prospective studies in the United States. *Obes Rev*. 2014;15(8):619–629. https://doi.org/10.1111/obr.12191.
57. Yu Y. The changing body mass–mortality association in the United States: evidence of sex-specific cohort trends from three National Health and Nutrition Examination Surveys. *Biodemography Soc Biol*. 2016;62(2):143–163. https://doi.org/10.1080/19485565.2015.1108835.
58. Stokes A, Ni Y. Validating a summary measure of weight history for modeling the health consequences of obesity. *Ann Epidemiol*. 2016;26(12):821–826. https://doi.org/10.1016/j.annepidem.2016.10.005.
59. Stommel M, Schoenborn CA. Accuracy and usefulness of BMI measures based on self-reported weight and height: findings from the NHANES & NHIS 2001–2006. *BMC Public Health*. 2009;9:421. https://doi.org/10.1186/1471-2458-9-421.
60. Perry G, Byers T, Mokdad A, Serdula M. The validity of self-reports of past body weights by U.S. adults. *Epidemiology*. 1995;6(1):61–66. https://doi.org/10.1097/00001648-199501000-00012.
61. Sorkin J, Muller D, Andres R. Longitudinal change in height of men and women: implications for interpretation of the body mass index. *Am J Epidemiol*. 1999;150(9):969–977. https://doi.org/10.1093/oxfordjournals.aje.a010106.