The Effects of Changes in Smoking Prevalence on Obesity Prevalence in the United States

Katherine M. Flegal, PhD

Objectives. Reduction of cigarette smoking is an important public health goal. However, lower smoking prevalence may be associated with increased obesity prevalence. I sought to estimate the effect of decreases in smoking prevalence on obesity prevalence in the United States population.

Methods. I combined current weight data by smoking status from the 1999–2002 National Health and Nutrition Examination Survey (NHANES) with smoking prevalence data from past NHANES surveys to estimate weight status had smoking prevalence not changed.

Results. Even relatively large changes in the prevalence of smoking were estimated to have little effect on obesity prevalence. For example, if smoking prevalence in 1999–2002 were at the higher 1971–1975 smoking level, the estimated 1999–2002 obesity prevalence would be 22.5% rather than the actual value of 23.9%, a difference of only 1.4 percentage points. Estimates for other weight categories were similarly small.

Conclusions. Decreases in the prevalence of cigarette smoking probably had only a small effect, often less than 1 percentage point, on increasing the prevalence of obesity and decreasing the prevalence of healthy weight in the population. (*Am J Public Health.* 2007;97:1510–1514. doi:10.2105/AJPH.2005.084343)

Reducing the prevalence of cigarette smoking is an important public health goal because of the strong association of tobacco use with disease and premature mortality.[1,2] As a result of intensive campaigns of public health information, social pressures, and environmental changes such as smoke-free restaurants and bars, smoking prevalence among adults in the United States has steadily declined.[3,4] One of the Healthy People 2010 goals (goal 27–1) is to reduce cigarette smoking among adults from 24% in 1998 to 12% by 2010.[5]

Obesity is also a risk factor for many diseases and conditions, such as hypertension, hypercholesterolemia, and diabetes.[5] The prevalence of obesity has been increasing in the United States for several decades.[6,7] Two of the Healthy People 2010 goals are to reduce the prevalence of obesity among adults to 15% from 23% (goal 19–2) and to increase the prevalence of healthy weight to 60% from 42% (goal 19–1).

Smoking is associated with lower weight,[8] and smoking cessation is associated with weight gain.[9,10] Reductions in smoking prevalence have been suggested as one of the factors associated with an increase in obesity.[11] This suggests the possibility that progress toward the public health goal of reducing cigarette smoking might potentially lead to increases in the prevalence of obesity, thus having an adverse effect on the goals of decreasing obesity and increasing the prevalence of healthy weight. My objective was to estimate the potential impact of changes in smoking prevalence on the prevalence of weight categories, including healthy weight and obesity.

METHODS

All data used came from the National Health and Nutrition Examination Survey (NHANES) series conducted by the Centers for Disease Control and Prevention's (CDC's) National Center for Health Statistics. In each of these cross-sectional multipurpose surveys, a representative sample of the US civilian noninstitutionalized population was selected according to a complex multistage cluster sample design. Descriptions of the plan and operation of previous surveys have been published elsewhere.[12–15] Participants were interviewed in the household and then underwent a standardized physical examination conducted in a mobile examination center.

Estimates for the current US population were derived from NHANES 1999–2002. Past smoking data were derived from the first, second, and third NHANES surveys (NHANES I, 1971–1975; NHANES II, 1976–1980; NHANES III, 1988–1994). The analytic sample used for all surveys consisted of all adults aged 25 to 74 years at examination who had data on weight, height, and cigarette smoking. Because the oldest age in NHANES I and NHANES II was 74 years, that age was used as the upper age limit, although NHANES III and NHANES 1999–2002 also included older participants. The final analytic sample consisted of 12 464 participants from NHANES I, 9053 participants from NHANES II, 14 468 participants from NHANES III, and 6774 participants from NHANES 1999–2002.

Variables

In all surveys, participants were asked if they had smoked at least 100 cigarettes in their lifetime. If they responded in the affirmative, they were then asked if they smoked "now." Participants who replied yes to the second question were considered to be current smokers; all others were considered to be nonsmokers.

Body weight and height were measured in the mobile examination center using standardized procedures and equipment. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Following federal guidelines,[16] obesity was defined as a BMI of 30 kg/m^2 or greater; overweight, as a BMI of 25 kg/m^2 to 29.9 kg/m^2; healthy weight, as a BMI of 18.5 kg/m^2 to 24.9 kg/m^2; and underweight, as a BMI less than 18.5 kg/m^2. Age was reported by the participants and was categorized into 3 groups: 25–39 years, 40–59 years, and 60–74 years. Race was categorized as White/Other or Black, and educational levels were categorized as less than high school, high school, or more than high school.

Statistical Methods

Data were analyzed with SAS 9.1 (SAS Institute Inc, Cary, NC) and SUDAAN 9.0 (Research Triangle Institute, Research Triangle Park, NC). All analyses included sample weights that account for the unequal probabilities of selection because of oversampling and nonresponse. All variance calculations incorporate the sample weights and account for the complex sample design.

A "counterfactual" analysis (that is, contrary to the facts) was carried out to estimate the prevalence of obesity (and other weight categories) if participants' smoking status had been different than it truly was; this analysis was adjusted for sociodemographic factors. Adjustments were carried out by dividing participants into subgroups based on gender, age group, race, educational level, and combinations of all 4 covariates. This is equivalent to fully adjusting for all these characteristics and their possible interactions. The overall results were almost identical for all sets of analyses, and only the results by gender and age group are presented.

In order to estimate the impact of changes in smoking prevalence, the current (NHANES 1999–2002) population was divided into subgroups. Within each subgroup, the prevalence of smoking was calculated for the entire subgroup and the probability of being obese was calculated separately for smoking and for nonsmoking participants.

Within each subgroup, the prevalence of obesity can be re-expressed as a function of the prevalence of smoking and the conditional prevalence of obesity for smokers and for nonsmokers as follows:

$$(1)\quad P(Ob) = P(Ob\,S)P(S) + P(Ob\,N)(1 - P[S]),$$

where P(Ob) is the prevalence of obesity, P(Ob S) is the prevalence of obesity among smokers, P(S) is the prevalence of smoking, and P(Ob N) is the prevalence of obesity among nonsmokers.

To examine the impact of changes in smoking, the higher smoking prevalence from earlier surveys was submitted for the NHANES 1999–2000 smoking prevalence. A predicted probability of obesity was calculated within each subgroup as follows:

$$(2)\quad P(Ob^*) = P(Ob\,S)P(S^*) + P(Ob\,N)(1 - P[S^*]),$$

where P(Ob*) is the predicted prevalence of obesity based on past smoking prevalence and current obesity rates among smokers and nonsmokers and P(S*) is past smoking prevalence. This is the expected prevalence of obesity within this subgroup in NHANES 1999–2002 if smoking rates were the same higher rates as in the past, but the probability of an individual being obese, conditional on smoking status, was the same as in the present. From the above formulas, it can be shown that the predicted change in obesity prevalence within a subgroup can be expressed as the product of the change in smoking prevalence and the difference in the probability of obesity among smokers and nonsmokers:

$$(3)\quad P(Ob) - P(Ob^*) = (P[S^*] - P[S])(P[Ob\,S] - P[Ob\,N])$$

Estimates for the entire population were calculated by summing these results over subgroups defined by sociodemographic factors (equivalent to adjusting for these factors). Similar analyses were carried out for overweight, healthy weight, and underweight. The prevalence of obesity among nonsmokers, summed over subgroups, was used as the estimate for the expected population prevalences if smoking were completely eliminated.

RESULTS

The distribution of the NHANES 1999–2002 sample among gender–age subgroups is shown in Table 1 along with the prevalence of smoking and obesity within each group. The probability of obesity among smokers and nonsmokers is also shown in Table 1. Within each gender–age subgroup, the estimated probability of obesity tended to be considerably higher among nonsmokers than among smokers. These differences between smokers and nonsmokers (Table 1) were larger and statistically significant ($P < .05$) within each age group for men. For women, the differences in obesity prevalence between smokers and nonsmokers were smaller and were statistically significant only for the total (36.3% in nonsmokers vs 31.4% in smokers, $P < .05$) but not within age groups.

The trends in reported smoking prevalence by gender and age group are shown in Table 2. Within each subgroup, the prevalence of smoking declined over the period covered by the surveys, from 1971 to 2002. Many of the

TABLE 1—Weighted Prevalence of Smoking and Obesity, and Prevalence of Obesity in Smokers and Nonsmokers, by Gender and Age Group: National Health and Nutrition Examination Survey (NHANES) 1999–2002

	Unweighted Sample Size	Proportion of the Sample Ages 25–74 y, %	Prevalence of Smoking, %	Prevalence of Obesity, %	Prevalence of Obesity in Nonsmokers, %	Prevalence of Obesity in Smokers, %
Men						
Age, y						
25–39	1137	20.1	32.3	23.8	26.3	18.5[a]
40–59	1279	21.1	27.3	30.2	32.6	23.7[a]
60–74	991	8.3	16.4	34.2	37.7	16.5[a]
Women						
Age, y						
25–39	1088	18.2	28.3	30.4	30.9	29.1
40–59	1286	22.5	21.9	37.0	37.9	33.7
60–74	993	9.8	13.7	39.9	41.2	31.7

Note. Data taken from only those participants of the NHANES 1999–2002 with complete data on weight, height, and smoking status.
[a]Significantly different from nonsmokers at $P < .05$.

TABLE 2—Weighted Prevalence of Cigarette Smoking, by Gender, Age, and Survey Wave: National Health and Nutrition Examination Survey (NHANES), 1971–2002

Age	NHANES I (1971–1975), %	NHANES II (1976–1980), %	NHANES III (1988–1994), %	NHANES 1999–2002, %
Men				
Age, y				
25–39	50.4	45.3	37.7	32.3
40–59	46.5	42.6	33.0	27.3
60–74	31.2	27.3	19.3	16.4
Women				
Age, y				
25–39	39.9	41.4	32.1	28.3
40–59	35.2	33.1	24.4	21.9
60–74	18.1	20.9	17.3	13.7

Note. Data taken from only those participants of the NHANES 1999–2002 with complete data on weight, height, and smoking status.

TABLE 3—Predicted and Actual Prevalence of Obesity in 1999–2002, by Gender and Age: National Health and Nutrition Examination Survey (NHANES)

	Predicted Prevalence,[a] %				
	NHANES I (1971–1975)	NHANES II (1976–1980)	NHANES III (1988–1994)	Actual Prevalence, %	Predicted Prevalence if No One Smoked, %
Total	30.7	30.9	31.4	31.8	33.5
Men					
Age, y					
25–39	22.4	22.8	23.4	23.8	26.3
40–59	28.5	28.9	29.7	30.2	32.6
60–74	31.1	31.9	33.6	34.2	37.7
Women					
Age, y					
25–39	30.2	30.2	30.3	30.4	30.9
40–59	36.4	36.5	36.9	37.0	37.9
60–74	39.5	39.3	39.6	39.9	41.2

Note. Data taken from only those participants of the NHANES 1999–2002 with complete data on weight, height, and smoking status. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Following federal guidelines,[16] obesity was defined as a BMI of 30 kg/m^2 or greater.

[a]Shown is the predicted prevalence of obesity in the NHANES 1999–2002 if smoking prevalence were the same as in past surveys.

declines were large. For example, in NHANES I, 50.4% of men aged 25–39 years smoked; by NHANES 1999–2002, the prevalence of smoking in this group had fallen to 32.4%.

The predicted prevalence of obesity in the NHANES 1999–2002—if smoking prevalence were the same as in past surveys—is shown in Table 3 for each gender–age subgroup. These values are calculated by substituting the past higher smoking prevalence into equation 2 while retaining the 1999–2002 survey values for the probability of obesity based on smoking status. Table 3 also presents the predicted prevalence for the entire sample, calculated as a weighted sum of the predicted prevalence within each gender–age subgroup. Tables 4–6 show the predicted prevalence of overweight, healthy weight, and underweight if smoking prevalence were the same as in past surveys.

The differences between the actual prevalence and the predicted prevalences based on past smoking rates were small. For example, for men aged 25–39 years, the prevalence of smoking dropped from 50.4% to 37.7% over the time period covered by the surveys. However, if the smoking rate were still 50.4% for that gender–age group, the predicted percent of the population classified as obese would have been only 1.4% lower (22.5% vs 23.9%). Similar results were noted in all gender–age subgroups. The estimated total impact of the changes in smoking between NHANES I and NHANES 1999–2002 was an increase of 1.1% in the prevalence of obesity in the population. The impact of the changes in smoking prevalence between NHANES III and NHANES 1999–2002 was smaller, 0.2%.

Results for overweight (Table 3) were similar to, but smaller than, those observed for obesity, with an overall effect of prevalence being higher by 0.1%. The prevalence of healthy weight (Table 3) was generally lower with decreasing prevalence of cigarette smoking. In most subgroups, the actual 1999–2002 prevalence of healthy weight was slightly lower than would be predicted if smoking prevalence rates had not decreased, with the overall impact being a difference of 0.2%, and the prevalence of underweight was slightly higher. In all subgroups, the impact was small.

The expected prevalence of obesity if smoking were to be completely eliminated is also shown in Table 3. In this case, the overall prevalence of obesity would be predicted to rise by a further 1.7%, from 31.8% to 33.5%. Across subgroups, the predicted increase ranged from 0.5% to 3.4%.

DISCUSSION

Large declines in smoking prevalence have occurred in the United States,[3,4] a result of both smoking cessation and lower smoking-initiation rates. The prevalence of obesity has also increased markedly over the same time period.[6,7] Smoking is associated with lower body weights and with a lower prevalence of obesity.[8–10] Thus it is reasonable to assume that part of the increase in obesity may be because of decreases in smoking prevalence.

TABLE 4—Predicted and Actual Prevalence of Overweight in 1999–2002, by Gender and Age: National Health and Nutrition Examination Survey (NHANES)

	Predicted Prevalence,[a] %				
	NHANES I (1971–1975)	NHANES II (1976–1980)	NHANES III (1988–1994)	Actual Prevalence, %	Predicted Prevalence if No One Smoked, %
Total	34.9	35.0	35.1	35.2	35.6
Men					
Age, y					
25–39	39.4	39.6	39.8	40.0	41.2
40–59	43.1	43.3	43.8	44.1	45.5
60–74	41.5	41.6	41.9	42.0	42.6
Women					
Age, y					
25–39	28.5	28.6	28.1	27.9	26.4
40–59	26.8	26.9	27.0	27.0	27.3
60–74	32.7	32.6	32.7	32.8	33.2

Note. Data taken from only those participants of the NHANES 1999–2002 with complete data on weight, height, and smoking status. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Following federal guidelines,[16] overweight was defined as a BMI of 25 kg/m^2 to less than 30 kg/m^2.
[a]Shown is the predicted prevalence of obesity in the NHANES 1999–2002 if smoking prevalence were the same as in past surveys.

TABLE 5—Predicted and Actual Prevalence of Healthy Weight in 1999–2002, by Gender and Age: National Health and Nutrition Examination Survey (NHANES)

	Predicted Prevalence,[a] %				
	NHANES I (1971–1975)	NHANES II (1976–1980)	NHANES III (1988–1994)	Actual Prevalence, %	Predicted Prevalence if No One Smoked, %
Total	32.6	32.3	31.7	31.3	29.4
Men					
Age, y					
25–39	36.4	35.8	35.0	34.4	31.0
40–59	27.8	27.3	26.0	25.3	21.7
60–74	26.3	25.5	23.8	23.1	19.6
Women					
Age, y					
25–39	37.3	37.2	37.7	37.9	39.4
40–59	35.0	34.9	34.5	34.4	33.3
60–74	26.0	26.3	25.9	25.5	24.0

Note. Data taken from only those participants of the NHANES 1999–2002 with complete data on weight, height, and smoking status. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Following federal guidelines,[16] healthy weight was defined as a BMI of 18.5 kg/m^2 to less than 25 kg/m^2.
[a]Shown is the predicted prevalence of obesity in the NHANES 1999–2002 if smoking prevalence were the same as in past surveys.

Analyses of the effect of smoking cessation generally compare the weights of smokers before and after cessation. Previous research suggested that an approximately 2.3% increase in overweight among men between NHANES II and NHANES III and a 1.3% increase among women might be attributable to smoking cessation.[8] Those findings were based on a slightly different definition of overweight, as a BMI greater than 27.8 kg/m^2 for men or greater than 27.3 kg/m^2 for women. However, estimating the effects of lower smoking-initiation rates is less straightforward because there is no way to identify people who did not begin smoking but who would have started smoking in the past. These analyses model the prevalence of obesity as a function of age, gender, race, educational level, and smoking status. These analyses also assume that if a nonsmoker in 1999–2002 had instead been a smoker, the predicted value from the model, based on age, gender, race, educational level, and the counterfactual smoking status would be a reasonable estimate of that person's probability of obesity if he or she had been a smoker. But, even if this assumption is flawed, the anticipated effects of changes in smoking prevalence are sufficiently small that it is unlikely that the effects on the prevalence of obesity would be large.

Analyses adjusted for confounding by gender only produced essentially the same results as those adjusted for age, gender, race, and educational level, with differences of 0.1% at most (data not shown), suggesting that confounding by sociodemographic factors had little impact on these results. A limitation is that additional factors not included in the analysis, such as alcohol consumption or physical activity, might have also affected the results if the relation of BMI to smoking varied with alcohol consumption or physical activity level.

The results are based on nationally representative survey data with measured weights and heights. Smoking status is self-reported. In NHANES III, comparison of self-reported smoking data to measurements of serum cotinine (a metabolite of nicotine) suggested that self-reported smoking was reasonably consistent with measured nicotine exposures.[17]

Within all gender–age groups, smokers had a lower probability of obesity than did nonsmokers, sometimes considerably lower. Despite this, changes in the prevalence of smoking had only a small estimated impact overall on the population prevalence of obesity. To see why this is, consider a hypothetical example of 1000 people. A decline of 10% in smoking prevalence is a relatively large decline but only affects 10% of the population, or 100 people in this example. If, for example, the probability of obesity among smokers is 20% then 20% of those 100 people would be obese if that group were smokers, equivalent to 20 people or 2% of the

TABLE 6—Predicted and Actual Prevalence of Underweight in 1999–2002, by Gender and Age: National Health and Nutrition Examination Survey (NHANES)

	Predicted Prevalence,[a] %				
	NHANES I (1971–1975)	NHANES II (1976–1980)	NHANES III (1988–1994)	Actual Prevalence, %	Predicted Prevalence if No One Smoked, %
Total	1.9	1.9	1.8	1.7	1.4
Men					
Age, y					
25–39	1.9	1.8	1.8	1.7	1.5
40–59	0.6	0.6	0.5	0.5	0.2
60–74	1.1	1.0	0.7	0.7	0.1
Women					
Age, y					
25–39	4.0	4.0	3.9	3.8	3.3
40–59	1.8	1.8	1.7	1.7	1.5
60–74	1.8	1.9	1.8	1.8	1.6

Note. Data taken from only those participants of the NHANES 1999–2002 with complete data on weight, height, and smoking status. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m^2). Following federal guidelines,[16] underweight was defined as a BMI of less than 18.5 kg/m^2.
[a]Shown is the predicted prevalence of obesity in the NHANES 1999–2002 if smoking prevalence were the same as in past surveys.

total population. If the probability of obesity among nonsmokers is 30% then 30% of those 100 people would be obese if that group were nonsmokers, equivalent to 30 people or 3% of the total population. The remainder of the population would be unchanged. The population-level effect on obesity if that 10% of the population were nonsmokers rather than smokers would only be the difference between 2% and 3%. So the expected effect of 10% of the population being nonsmokers rather than smokers would only be a 1% increase in obesity in the total population. Thus, even though smoking cessation can have a considerable effect on the weight of an individual, and even though smokers tend to have a lower prevalence of obesity than nonsmokers, and even though drops in the prevalence of smoking have been large, nonetheless the likely effect of changes in smoking prevalence on obesity in the whole population is not large.

The estimated impact of declines in smoking prevalence is generally to increase the prevalence of obesity and overweight and to decrease the prevalence of healthy weight and underweight. However, in all cases the effects are small. These analyses suggest that decreases, even substantial decreases, in the prevalence of cigarette smoking would likely have only a small effect, generally less than 1%, on increasing the prevalence of obesity and decreasing the prevalence of healthy weight. ■

About the Authors

Katherine M. Flegal is with the National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, Md.

Requests for reprints should be sent to Katherine M. Flegal, National Center for Health Statistics, Centers for Disease Control and Prevention, 3311 Toledo Rd, Room 4201, Hyattsville, MD 20782 (e-mail: kflegal@cdc.gov).

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