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THE INFLUENCE OF SMOKING CESSATION ON THE PREVALENCE OF OVERWEIGHT IN THE UNITED STATES

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Abstract Background. The proportion of U.S. adults 35 to 74 years of age who were overweight increased by 9.6 percent for men and 8.0 percent for women between 1978 and 1990. Since the prevalence of smoking declined over the same period, smoking cessation has been suggested as a factor contributing to the increasing prevalence of overweight.

Methods. To estimate the influence of smoking cessation on the increase in the prevalence of overweight, we analyzed data on current and past weight and smoking status for a national sample of 5247 adults 35 years of age or older who participated in the third National Health and Nutrition Examination Survey, conducted from 1988 through 1991. The results were adjusted for age, socio-demographic characteristics, level of physical activity, alcohol consumption, and (for women) parity.

Results. The weight gain over a 10-year period that was associated with the cessation of smoking (i.e., the gain among smokers who quit that was in excess of the gain among continuing smokers) was 4.4 kg for men and 5.0 kg for women. Smokers who had quit within the past 10 years were significantly more likely than respondents who had never smoked to become overweight (odds ratios, 2.4 for men and 2.0 for women). For men, about a quarter (2.3 of 9.6 percentage points) and for women, about a sixth (1.3 of 8.0 percentage points) of the increase in the prevalence of overweight could be attributed to smoking cessation within the past 10 years.

Conclusions. Although its health benefits are undeniable, smoking cessation may nevertheless be associated with a small increase in the prevalence of overweight. (N Engl J Med 1995;333:1165-70.)

THE proportion of adults in the United States who were overweight increased markedly between 1978 and 1990.¹ The reported prevalence of smoking in the country declined steadily during the same period.² These two important public health issues are interrelated, because smoking is associated with lower body weight, on average, and the cessation of smoking is associated with weight gain.³⁻⁵ The decrease in the prevalence of smoking may thus be one factor contributing to weight gain in the U.S. population.⁶ We estimated the association between smoking cessation and both weight gain and the increase in the prevalence of overweight in the United States, using data on a representative sample of the population.

METHODS

Study Population and Design

Phase 1 of the third National Health and Nutrition Examination Survey (NHANES III) was conducted from 1988 through 1991 by the National Center for Health Statistics of the Centers for Disease Control and Prevention.⁷ A nationally representative sample of the civilian, noninstitutionalized U.S. population was selected by means of a complex, stratified, multistage probability-cluster sampling design. Informed consent was obtained from all respondents, and the proto-

col was reviewed and approved by the institutional review board at the National Center for Health Statistics. For each participant, an interview in the home was followed by a physical examination in a mobile examination center.

Sociodemographic Characteristics

Each respondent's race or ethnic group was categorized as non-Hispanic white, non-Hispanic black, Mexican American, or other, on the basis of the respondent's statement. The respondents were assigned to one of the following age groups: 35 to 39, 40 to 49, 50 to 59, 60 to 69, or 70 or more years. Educational level was categorized as less than 12, 12, or more than 12 completed years of schooling. The respondents' marital status was categorized as either married or "other." The regions where the respondents lived were classified according to the U.S. Census definitions as Northeast, Central, South, or West. The places of residence were further classified according to the degree of urbanization, according to the U.S. Census definitions of central cities and Standard Metropolitan Statistical Areas (SMSAs), as follows: central city in an SMSA, non-central city in an SMSA, or non-SMSA.

Weight and Height

Weight and height were measured with standardized techniques and equipment.¹ Overweight was defined as a body-mass index (the weight in kilograms divided by the square of the height in meters) of 27.8 or higher for men and 27.3 or higher for women.⁸ During the home interview, respondents were asked to report their current body weight and their weight 10 years earlier. Data on weight 10 years earlier were not collected for participants under 35 years of age. The current reporting error was calculated as the difference between the reported and the measured current weight, expressed as a percentage of the measured weight. Each respondent's past weight was adjusted

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by his or her current reporting error. Weight change was calculated as the current measured weight minus the adjusted past weight.

Cigarette Smoking and Tobacco Use

We grouped the respondents into five categories according to their reported use of tobacco products. Respondents who had smoked fewer than 100 cigarettes in their lifetimes and had never used other forms of tobacco (cigars, pipes, snuff, or chewing tobacco) were classified as never having smoked. Others were classified as current cigarette smokers if they currently smoked cigarettes regularly, as current users of other forms of tobacco if they currently used some other form of tobacco but did not smoke cigarettes, and as former smokers if they had previously smoked cigarettes or used other forms of tobacco but currently did neither. Former smokers were further classified as having quit less than 10 years ago or 10 or more years ago, on the basis of their reported age when they quit smoking cigarettes or stopped using snuff or chewing tobacco. Data on age at the time of quitting pipe or cigar smoking were not available in the NHANES.

Other Covariates

Respondents were asked how often they engaged in walking and specified leisure-time physical activities. The intensity of these activities was coded as moderate or high on the basis of the energy expenditure they required, expressed as metabolic equivalents (MET; 1 MET is defined as the amount of energy expended per minute by a subject resting quietly).⁹ The subjects were classified as engaging in moderate activity (3 to 5 MET) fewer than five or five or more times per week and as engaging in vigorous activity (>5 MET) fewer than three or three or more times per week. Women were categorized as having had 0, 1, 2, 3, 4, 5, or ≥ 6 live-born children, with births occurring 10 or more years ago and less than 10 years ago coded separately. The reported number of alcoholic drinks consumed per week was included as a continuous variable. Respondents who reported having consumed 5 or more drinks almost every day in the past but fewer than 12 drinks in the previous year were categorized as former heavy drinkers.

Statistical Analysis

Weight and height were measured for 5837 nonpregnant adults 35 years of age or older. We excluded respondents who had begun smoking within the past 10 years ($n=36$), respondents with missing values for past weight ($n=302$) or reported current weight ($n=106$), former smokers for whom the age at smoking cessation was missing ($n=29$), and former pipe or cigar smokers who had never smoked cigarettes ($n=117$), leaving a sample of 5247 respondents for analysis.

Values were adjusted for the age distribution of the 1980 U.S. Census population by the direct method. Mean differences among smoking categories were adjusted by analysis of covariance for age (with use of linear and quadratic terms), sociodemographic characteristics (race or ethnic group, educational level, geographic region, marital status, and degree of urbanization of residence), height, physical-activity level, alcohol consumption, and parity (in the case of women); these are referred to as fully adjusted differences. For categorical outcomes, adjusted odds ratios, with subjects who had never smoked as the reference category, were estimated from logistic-regression models with the same covariates. Some analyses also included past body-mass index and the number of cigarettes the respondent had smoked before quitting.

Logistic-regression models were fitted to estimate the probability of being currently overweight according to age, sociodemographic factors, height, past body-mass index, physical-activity level, alcohol consumption, parity, and smoking status. Two hypothetical conditions were then simulated with these models. The first simulation estimated the prevalence of overweight that would have been expected if those who had quit smoking within the past 10 years had instead continued to smoke, and the second estimated the expected prevalence of overweight if all current smokers had quit. For each simulation, the smoking categories were modified to correspond to the simulated condition, and the coefficients from the original logistic-regression models were used to calculate a new probability of being overweight from each subject's modified smoking category and the other factors in the model. For the first simulation, those who had quit smoking within the

past 10 years were reassigned to the current-smoker category. For the second simulation, current smokers were reassigned to the category of those who had quit smoking within the past 10 years.

Statistical analyses were carried out with SAS¹⁰ and SUDAAN¹¹ software. All analyses incorporated sampling weights that took into account the unequal probability of selection. The calculations of variance estimates took into account the complex sampling design. Ninety-five percent confidence intervals were calculated with use of a t-statistic with 23 degrees of freedom.

RESULTS

Study Subjects

Selected characteristics of the study subjects are shown in Table 1. On average, the current smokers were less physically active than the other respondents and drank somewhat more. Former smokers included a higher proportion of non-Hispanic whites than current smokers or those who had never smoked, were more likely to be married, and drank less on average than current smokers. The group that had never smoked had the highest proportion of women, and its members, on average, drank the least and were the least likely to be former heavy drinkers. Users of other forms of tobacco were predominantly male, tended to have lower educational levels than the other groups, were more likely to reside in the South, and were less likely to reside in the central city of an SMSA.

Overweight and Body-Mass Index, According to Smoking Status

Age-adjusted values for the prevalence of overweight, mean body-mass index, and mean changes in body-mass index and weight over the previous 10 years are shown in Table 2. Current smokers, both male and female, had the lowest age-adjusted prevalence of overweight and the lowest mean body-mass index of all groups.

Those who had quit smoking within the previous 10 years had the highest age-adjusted changes in body-mass index and weight. They had gained significantly more weight than those who had never smoked; the fully adjusted mean differences in weight gain were 3.6 kg (95 percent confidence interval, 1.5 to 5.6) for men and 3.3 kg (95 percent confidence interval, 0.9 to 5.7) for women. Those who continued to smoke gained less, but not significantly less, than those who had never smoked; the fully adjusted mean differences in weight gain were -0.9 kg (95 percent confidence interval, -2.5 to 0.8) for men and -1.7 kg (95 percent confidence interval, -3.6 to 0.3) for women. The age-adjusted estimate of the amount of weight gain due to smoking cessation (the difference between the weight gain among those who stopped smoking and the weight gain among continuing smokers) was 3.5 kg for men and 5.5 kg for women. The fully adjusted estimate of the amount of weight gain due to smoking cessation was 4.4 kg (95 percent confidence interval, 2.5 to 6.3) for men and 5.0 kg (95 percent confidence interval, 2.0 to 8.0) for women.

Sex-specific linear-regression models were used to identify factors associated with weight gain among

those who had quit smoking within the past 10 years. For men, higher past body-mass index, shorter height, current residence in the South, and current residence in the central city of an SMSA were significantly associated with lower weight gain. For women, higher parity 10 years earlier and the number of cigarettes smoked before quitting were significantly associated with greater weight gain. When variables that could have changed within the past 10 years were excluded, the significant predictors of greater weight gain among those who had quit smoking in the past 10 years were greater height and lower past body-mass index for men and greater height for women.

Weight Gain of 15 kg or More

Sixteen percent of the men and 21 percent of the women who had quit smoking within the past 10 years gained 15 kg or more. The adjusted odds ratios for gaining 15 kg or more in this group as compared with subjects who had never smoked were 2.45 (95 percent confidence interval, 1.24 to 4.87) for men and 1.87 (95 percent confidence interval, 0.93 to 3.73) for women who had quit smoking within the past 10 years; among the men, the odds of gaining 15 kg or more were significantly different only from the odds of such a gain among those who had never smoked. In the other smoking-status groups, the odds of gaining 15 kg or more were not significantly different from the odds among those who had never smoked. Among those who had quit smoking in the past 10 years, the significant predictors of a weight gain of 15 kg or more were height for men and, for women, the number of cigarettes smoked per day before quitting (adjusted odds ratio per 10 cigarettes, 1.68; 95 percent confidence interval, 1.17 to 2.40) and the number of children born alive 10 or more years earlier (adjusted odds ratio per live birth, 1.58; 95 percent confidence interval, 1.17 to 2.14).

Past and Current Overweight

The fully adjusted odds ratios for having been overweight 10 years earlier, remaining overweight (among those who were overweight 10 years earlier), and becoming overweight (among those who were not over-

Table 1. Selected Characteristics of the Study Subjects, According to Smoking Category.

CHARACTERISTIC	NEVER SMOKED	QUIT ≥10 Yr EARLIER	QUIT <10 Yr EARLIER	CURRENT CIGARETTE SMOKER	OTHER TOBACCO USER
Unweighted sample size	1990	1063	609	1332	253
Male sex (%)	26.4	59.4	51.7	54.1	85.5
Mean age (yr)	54.3	59.0	53.2	50.2	57.7
Race or ethnic group (%)					
Non-Hispanic white	78.3	87.5	86.4	78.2	86.4
Non-Hispanic black	9.4	7.0	6.3	13.0	11.2
Mexican American	4.1	3.0	3.7	2.8	0.4
Other	8.2	2.5	3.6	6.0	2.0
Educational level (%)					
<12 yr	24.9	25.3	30.2	32.5	49.9
12 yr	33.1	29.3	28.1	33.7	17.8
>12 yr	42.1	45.4	41.8	33.8	32.3
Region (%)					
Northeast	19.7	24.2	20.6	21.5	14.8
Central	24.3	22.7	21.7	24.5	24.1
South	33.9	30.6	37.4	35.0	55.2
West	22.2	22.5	20.3	19.1	5.9
Urbanization (%)					
Central city in SMSA	26.6	23.9	22.6	23.7	10.9
Non-central city in SMSA	51.6	57.1	59.8	55.4	51.3
Non-SMSA	21.8	19.0	17.7	21.0	37.8
Married (%)	68.1	75.8	70.6	67.6	74.0
Physical-activity level (%)					
Moderate (3–5 MET) ≥5 times/wk	35.6	43.7	36.4	33.1	37.9
High (>5 MET) ≥3 times/wk	9.0	9.7	8.8	5.2	8.8
Alcohol consumption					
Former heavy drinking (%)	0.7	5.4	7.9	7.6	7.2
Mean no. of drinks/wk	1.7	3.4	4.0	6.3	5.6
Mean parity (for women only)	2.5	2.4	2.5	2.6	3.2

Table 2. Age-Adjusted Prevalence of Overweight, Body-Mass Index, and Change in the Body-Mass Index and Weight over the Past 10 Years, According to Sex and Smoking Category.*

SEX AND SMOKING CATEGORY	PREVALENCE OF OVERWEIGHT %	MEAN BMI	MEAN INCREASE IN BMI	MEAN INCREASE IN WEIGHT kg
Men				
Never smoked	36.6±2.88	26.9±0.35	0.45±0.15	1.49±0.44
Quit ≥10 yr earlier	40.4±2.32	27.3±0.24	0.74±0.14	2.39±0.43
Quit <10 yr earlier	46.5±4.13	27.9±0.27	1.67±0.19	5.28±0.59
Current smoker	27.6±1.68	25.8±0.24	0.58±0.13	1.82±0.39
Other tobacco user	40.6±4.62	27.4±0.66	0.13±0.61	0.46±2.07
Women				
Never smoked	41.6±2.48	27.2±0.26	1.42±0.15	3.75±0.41
Quit ≥10 yr earlier	35.3±5.00	26.7±0.52	1.80±0.46	4.75±1.20
Quit <10 yr earlier	42.1±3.60	27.7±0.48	3.15±0.34	8.46±0.91
Current smoker	32.8±2.10	25.6±0.22	1.11±0.23	2.96±0.61
Other tobacco user	51.9±7.45	26.9±0.72	1.43±0.76	4.05±1.96

*Values are means ±SE. BMI denotes body-mass index.

weight 10 years earlier) are shown in Table 3. Current smokers were less likely than those who had never smoked to have been overweight 10 years earlier, to remain overweight, and to become overweight, although not all these differences were statistically significant. Former smokers who had quit more than 10 years earlier did not differ significantly from those who had never smoked. However, former smokers who had quit smoking within the past 10 years were significantly more likely than those who had never

Table 3. Adjusted Odds Ratios for Being Overweight 10 Years Earlier, Remaining Overweight, or Becoming Overweight, According to Sex and Smoking Category.*

SEX AND VARIABLE	QUIT ≥10 YR EARLIER	QUIT <10 YR EARLIER	CURRENT SMOKER
<i>odds ratio (95% confidence interval)</i>			
Men			
Overweight 10 years earlier	1.17 (0.81–1.73)	0.92 (0.54–1.58)	0.69 (0.44–1.07)
Remaining overweight	1.03 (0.51–2.08)	1.50 (0.47–4.85)	0.52 (0.27–0.98)†
Becoming overweight	1.08 (0.58–2.02)	2.42 (1.02–5.77)†	0.65 (0.33–1.31)
Women			
Overweight 10 years earlier	0.89 (0.55–1.45)	0.96 (0.56–1.64)	0.62 (0.43–0.89)†
Remaining overweight	0.83 (0.46–1.52)	1.45 (0.54–3.92)	0.50 (0.19–1.34)
Becoming overweight	1.32 (0.70–2.47)	2.02 (1.04–3.94)†	0.90 (0.49–1.63)

*For all odds ratios, the reference category is respondents who never smoked. Odds ratios have been adjusted for age, race or ethnic group, educational level, geographic region, degree of urbanization, marital status, height, physical-activity level, alcohol consumption, and parity.

†Significantly different from 1.00 (P<0.05).

smoked to become overweight and also more likely to remain overweight.

The Effect of Smoking Cessation on the Increase in the Prevalence of Overweight

Between the second and third NHANES surveys (NHANES II and NHANES III), the prevalence of overweight in the U.S. population increased by 9.6 percent for men and 8.0 percent for women from 35 to 74 years of age. To estimate the extent to which this increase was due to smoking cessation, we calculated the prevalence of overweight that would have been expected in NHANES III if those who had quit smoking within the past 10 years had instead continued to smoke (Table 4). The predicted prevalence of overweight for this group of former smokers was 15.7 percentage points lower than the actual prevalence for men and 10.3 percentage points lower for women. The predicted age-adjusted prevalence of overweight for the entire U.S. population was 2.3 percentage points lower than the actual prevalence for men and 1.3 percentage points lower for

women. These estimates represent the part of the increase in the prevalence of overweight that can be attributed to smoking cessation.

We also calculated the prevalence of overweight that would have been expected if all current smokers had quit smoking within the past 10 years (Table 4). The predicted prevalence of overweight among current smokers was 14.2 percentage points higher than the actual prevalence for men and 8.9 percentage points higher for women. The predicted age-adjusted prevalence of overweight for the entire population was 3.9 percentage points higher than

the actual prevalence for men and 1.8 percentage points higher for women. These estimates represent the additional increase in the prevalence of overweight that would have been expected if all current smokers had instead quit smoking.

DISCUSSION

Smoking cessation has been suggested as a possible contributing factor to the increase in the prevalence of overweight in the United States.^{1,6} In our study, we estimated the association between smoking cessation and the increased prevalence of overweight in the U.S. population, using data from a representative national sample, with adjustments for age and for sociodemographic and behavioral characteristics.

Among smokers who had quit within the past 10 years, there was a large increase in the prevalence of overweight. However, because this group made up a relatively small percentage of the population, the net effect of smoking cessation on the prevalence of overweight in the population as a whole was small. Among men, approximately a quarter of the increase in overweight (2.3 of 9.6 percentage points) and among women, approximately a sixth (1.3 of 8.0 percentage points) could be attributed to the cessation of smoking. These results suggest that smoking cessation accounts for a small part of the recent increase in the prevalence of overweight in the U.S. population. Boyle et al.¹² similarly concluded that increasing weight among Australians could not be explained by decreases in the prevalence of cigarette smoking.

Limitations of the Study

Because these data come from an observational study, our inferences are potentially biased by unmeasured differences in behavioral or

Table 4. Actual and Predicted Prevalence of Overweight among Men and Women 35 to 74 Years of Age in the NHANES III and NHANES II Population Samples.*

ORIGINAL CATEGORY	MEN			WOMEN		
	ACTUAL	PREDICTED IF NONE QUIT	PREDICTED IF ALL QUIT	ACTUAL	PREDICTED IF NONE QUIT	PREDICTED IF ALL QUIT
<i>percent prevalence of overweight</i>						
NHANES III (1988–1991)						
Never smoked	37.1			41.5		
Quit ≥10 yr earlier	43.9			36.2		
Quit <10 yr earlier	48.6	32.9		40.3	30.0	
Current smoker	28.3		42.5	34.1		43.0
Other tobacco user	40.6			54.4		
Other	34.8			48.3		
Total	37.5	35.3	41.5	39.9	38.8	41.9
Age-adjusted total	38.2	35.9	42.1	41.1	39.8	42.9
NHANES II (1976–1980)						
Age-adjusted total	28.6			33.1		
Increase between 1976–1980 and 1988–1991	9.6	7.3	13.5	8.0	6.7	9.8

*The predicted prevalence values shown are those that would have been expected if all respondents who quit smoking in the past 10 years had instead continued to smoke or if all who continued to smoke had quit. "Other" includes former smokers for whom data were missing on age at cessation or past or current reported weight.

health-related characteristics between respondents who quit smoking and those who continued to smoke. Our analysis used the respondents' reports of their smoking history and past weight, both of which are subject to error. Subjects' reported past weight has been found to be a reasonably valid measure.¹³⁻¹⁵ Mean body-mass index 10 years earlier calculated from the weight and height reported in NHANES III (25.7) was almost identical to the mean measured body-mass index in NHANES II (25.6), just over 10 years earlier, suggesting that, on average, past weights were reported fairly accurately in our study. Our findings rely largely on comparisons between smoking categories, not on absolute values for past weight. These comparisons could be biased if errors in the reporting of past weight differed among the smoking categories. To reduce the possible effects of differential reporting errors, we adjusted each respondent's past weight by his or her reporting error for current weight, a procedure that decreased the differences between smoking categories.

Weight Gain after Smoking Cessation

During 10 years of follow-up, we found a weight gain of 4.4 kg for men and 5.0 kg for women after smoking cessation. Our estimates are consistent with the findings of recent clinical and interventional studies, which have shown that a considerable amount of weight may be gained within the first few months to a year after the cessation of smoking. Average weight gains among subjects who continuously abstained from smoking in these studies include 3.6 kg in a 60-day period,¹⁶ 4.0 kg after 23 weeks,¹⁷ more than 4 kg after 26 weeks,¹⁸ 4.8 kg over 12 months,¹⁹ and 8.2 kg over 12 months.²⁰ However, our estimates of the average weight gain are somewhat higher than other estimates in the literature.^{3,21-23} The greater gains observed in our study occurred during a period when the prevalence of overweight was increasing generally and may be due partly to environmental factors that promoted greater weight increases.

We found no significant differences between those who had never smoked and those who had quit smoking more than 10 years previously. This lack of difference suggests that weight gain occurs shortly after smoking cessation and that former smokers do not continue to gain weight at a higher rate than those who have never smoked. However, former smokers who had quit smoking more than 10 years earlier were still more likely to be overweight than those who continued to smoke.

Interventions aimed at preventing weight gain after the cessation of smoking by the use of nicotine gum or through a behavioral weight-control program have had little success.^{19,24} To the extent that weight gain is a physiologic process reflecting nicotine withdrawal, successful intervention may be difficult. Weight gain follows promptly on smoking cessation; relapse or initiation of smoking is followed by weight loss.^{16,20,22,25} That our analyses found few sociodemographic or behavioral characteristics that predicted weight gain among re-

spondents who quit smoking also suggests a physiologic rather than a behavioral effect.

Concern over weight and weight gain, particularly among white women, young women, and both male and female adolescents, may be an important factor leading to the initiation and continuation of smoking.²⁶⁻³⁴ Reducing concern about weight gain after the cessation of smoking may be preferable to trying to prevent weight gain.³⁵

Implications

The 1990 report of the Surgeon General concluded that the health benefits of smoking cessation far exceeded the risks associated with weight gain and that smoking cessation had major and immediate health benefits for men and women of all ages.³⁶ This conclusion is supported by epidemiologic studies that examined the association between weight and mortality separately for smokers and nonsmokers.³⁷⁻⁴¹

At present, efforts to prevent weight gain immediately after the cessation of smoking appear relatively unsuccessful. Despite its long-term health benefits, stopping smoking may involve a gain of 4 to 5 kg or more. Rather than attempting to prevent this initial weight change, it may be more useful to attempt to limit further weight gain after that point.

The health benefits of smoking cessation are undeniable. Public health efforts to discourage the initiation of smoking and to promote its cessation must continue. To the extent these efforts are successful, they are likely to lead to further increases in the proportion of the population that is overweight. Nonetheless, it is important to discourage the use of smoking as a means of weight control and to encourage the cessation of smoking, while continuing research aimed at understanding and moderating the degree of weight gain among former smokers.

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