

Characteristics Associated with Excessive Weight Gain after Smoking Cessation in Men

ABSTRACT

Objectives. Data from two surveys of the National Academy of Sciences–National Research Council Twin Registry, conducted 16 years apart, were used to determine characteristics of individuals that were predictive of excessive weight gain after smoking cessation.

Methods. Over the follow-up, 2179 men quit smoking and averaged a weight gain of 3.5 kg. Quitters were grouped into four categories of weight change: lost weight, no change, gained weight, and excessive weight gain (“super-gainers”).

Results. In comparison with quitters reporting no change in weight, super-gainers were younger, were of lower socioeconomic status, and differed on a number of health habits before quitting (all P s < .05). At follow-up, super-gainers reported changes in health habits that were significantly different from those seen in quitters reporting stable weight (all P s < .05). Pairwise concordance for weight change in 146 monozygotic and 111 dizygotic twin pairs in which both twins quit smoking was significantly greater in monozygotic than dizygotic pairs (P < .01).

Conclusions. These results indicate that super-gainers differ in important ways from those who do not gain weight after smoking cessation and that these weight changes may be influenced by underlying genetic factors. (*Am J Public Health.* 1995;85: 73–77)

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Introduction

A majority of individuals who stop smoking subsequently gain weight.^{1,2} There is growing concern that increasing numbers of people smoke because of the associated weight control effect, fail to quit for fear of weight gain, or return to smoking after having quit because of the actual weight gain.³ The precise mechanisms underlying postcessation weight gain are not well understood.^{4,5}

Williamson et al.⁶ recently characterized a group of smokers who gained more than 13.0 kg after quitting over a 10-year follow-up of a national cohort. Weight gain of this magnitude may increase the risk for other health problems, such as hypertension and diabetes. In the Williamson et al. study, these “super-gainers” were more likely to be Black, under the age of 55, and heavier smokers who also were less obese before cessation. Beyond that study, however, there have been no other published characterizations of this group of quitters who are at risk for excessive postcessation weight gain.

Because of the health risks associated with excessive weight gain, the present study sought to further characterize prospectively a group of male former smokers from the National Academy of Sciences–National Research Council Twin Registry who gained weight excessively over a 16-year follow-up. In addition, we examined the concordance in weight gain and loss after smoking cessation⁷ in monozygotic and dizygotic twin pairs in which both twins quit smoking during the course of follow-up.

Methods

Study Population

The methods used to construct the National Academy of Sciences–National

Research Council Twin Registry have been described elsewhere.^{8,9} Members of the registry, consisting of adult male twins born in the United States between 1917 and 1927, were screened at entry into the armed forces during World War II; pairs in which one or both members had childhood diseases such as diabetes or hypertension were excluded from service and are therefore not part of the registry. An epidemiologic health questionnaire was mailed to registry members during 1967 through 1969 in a collaborative study with investigators of the Swedish Twin Registry.¹⁰

During 1983 through 1985, a follow-up questionnaire was administered to all respondents to the first survey. The completion rates were 78% for the 1967 through 1969 survey and 66% for the 1983 through 1985 survey; when corrected for mortality, these figures increase to 80% and 71%, respectively. Previous analyses of these data have focused on the heritability of smoking and drinking practices.^{11–13}

Self-reported smoking practices from the 1967 through 1969 survey and the 1983 through 1985 follow-up were used to construct the following three subgroups: (1) continuing nonsmokers (persons who reported at both surveys that they did not smoke currently), (2) quitters (those who were smokers in 1967 through 1969 but reported that they were ex-smokers in 1983 through 1985), and (3) continuing smokers (those who reported current smoking in 1967 through 1969 and at follow-up). In this cohort, 2179 men, or 34% of the respondents to both surveys,

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This paper was accepted May 17, 1994.

TABLE 1—Frequency of Subjects with Different Degrees of Weight Change, by Smoking Status during Follow-Up

Smoking Status	Weight Loss, ^a No. (%)	Stable Weight, No. (%)	Weight Gain, ^b No. (%)	Excessive Weight Gain, ^c No. (%)	Total
Continuing nonsmokers	573 (21)	1227 (45)	830 (30)	121 (4)	2751
Quitters	329 (15)	710 (33)	858 (39)	282 (13)	2179
Continuing smokers	366 (23)	655 (42)	456 (29)	92 (6)	1569
Total	1268	2592	2144	495	6499

^aLost more than 2.3 kg.^bGained more than 2.3 kg but less than 11.3 kg.^cGained 11.3 kg or more.

quit smoking during the follow-up. An additional 1569 men (24%) continued to smoke, while 2751 (42%) were nonsmokers at both surveys. A total of 94 subjects (1.4%) initiated smoking over the course of follow-up.

Self-reports of weight in pounds at the time of each epidemiologic survey and estimated weight at 25 years of age provided three weight assessments: early in adulthood, at baseline before quitting, and at follow-up. Weight change in quitters from baseline to follow-up was coded as a variable with four categories. The first category included individuals who lost weight (defined as losing more than 2.3 kg [5 lb] during the follow-up period; $n = 329$). The second category included those with no change in weight (a reported loss or gain of 2.3 kg or less; $n = 710$). The third category included those who gained more than 2.3 kg but less than 11.3 kg (25 lb; $n = 858$). The fourth category included those who gained 11.3 kg or more (super-gainers; $n = 282$).

Subjects were asked how many times they usually drank each of the three types of alcoholic beverages (beer, wine, and liquor) and, for each kind that they drank, how many drinks they usually consumed per drinking occasion. Alcohol consumption was computed by multiplying frequency of drinking occasion by the number of drinks for each type of alcohol at each occasion. The same questions about alcohol consumption were used in both the 1967 through 1969 and 1983 through 1985 surveys. Change in consumption was calculated by subtracting the 1967 through 1969 measures from the 1983 through 1985 measures.

Nutritional data were collected with a food frequency questionnaire similar to that used in the University of Rhode Island twin study.¹⁴ The questionnaire

assessed the amounts of various food items (e.g., candy, pastries, and coffee) consumed daily. In addition, subjects were asked at both surveys whether they had to diet to keep their weight down.

Physical exercise (outside of work) after 35 years of age was assessed at baseline by response to a single question that included the following categories: hardly any exercise, light exercise (e.g., gardening, regular walks), moderate exercise (e.g., swimming, tennis), and vigorous exercise (e.g., hard physical training). These categories were coded 1 to 4, with higher scores indicative of more strenuous activity.

A composite socioeconomic index was constructed from the subject's highest rank achieved in the military and occupation reported in the 1967 through 1969 survey. High scores on this index were indicative of a higher socioeconomic status (index score range 10–99; median 73; mean 67.6). Responses to items concerning heart attack, stroke, diabetes, and hypertension were used to construct a cardiovascular disease category. Positive reports of two or more conditions were coded 1, and reports of no conditions or one condition were coded 0.

Statistical Analysis

Analyses in this study were conducted with the statistical software package SAS.¹⁵ Characteristics of ex-smokers in the four weight change categories were compared, and the contrast between super-gainers and those reporting stable weight was evaluated. Both univariate and multivariate comparisons were conducted to identify (1) baseline characteristics of quitters that were associated with subsequent weight change during follow-up and (2) associations between change in a subset of variables for which data were

available at follow-up, including alcohol and coffee consumption and food habits, and concomitant change in weight following smoking cessation. The analysis of variance procedure with the Duncan multiple comparison test was used in the univariate analyses. When significant differences were identified, the analyses were repeated with age, socioeconomic status, and baseline weight included as covariates. Since overall results did not change with this adjustment, we report the unadjusted means for all four weight change categories. In the comparison of super-gainers with those reporting stable weight, the dependence on observations from members of a twin pair may have produced spuriously low standard errors and narrower confidence intervals (CIs) than those reported. We believe, however, that this effect was small, given that only 112 subjects (56 pairs) of the total of 992 (282 super-gainers and 710 quitters with stable weight) were genetically related.

The pairwise concordance rate was calculated to determine whether genetic effects contributed to twin similarity in weight change after smoking cessation. This rate was defined as $C/(C + D)$, where C is the number of pairs concordant for weight change and D is the number of discordant pairs. A greater concordance rate in monozygotic than in dizygotic twins was tested by a one-sided z test of the difference between the two proportions.

Results

Characteristics of Quitters

At baseline, individuals who eventually quit smoking at follow-up were, on average, 46.3 years of age; had an average body mass index of 24.7, and smoked an average of 24.3 cigarettes per day. To facilitate comparison with the quitters in the Williamson et al.⁶ study, we also created the following subgroups by number of cigarettes smoked per day: 1 to 14 (18.4%), 15 to 24 (37.6%), and 25 or more (44%). Continuing smokers, on average, were 46.0 years of age, had a body mass index of 24.5, and smoked 27.1 cigarettes per day. On average, those who remained nonsmokers over the course of follow-up were 46.4 years of age and had a body mass index of 25.0. Over the course of follow-up, quitters gained a reported average of 3.5 kg (SD = 6.9), whereas continuing smokers reported a gain of 0.9 kg (SD = 6.8). Continuing nonsmokers reported a gain of 1.1 kg (SD = 5.7).

TABLE 2—Subjects' Demographics and Health Behaviors at Baseline (1967 through 1969), by Weight Gain Category

Characteristic	Lost Weight	Stable Weight	Gainers	Super-Gainers	Overall Significance	Comparison between Stable Weight Gainers and Super-Gainers ^a (95% CI)
Age, y (mean ± SD)	47.0 ± 3.1 _a	46.5 ± 2.9 _b	46.0 ± 2.9 _c	45.9 ± 3.0 _c	<.001	0.6 (0.1, 0.9)*
Socioeconomic status, rank (mean ± SD)	70.9 ± 23.6 _a	71.2 ± 23.5 _a	70.1 ± 23.3 _a	66.2 ± 23.7 _b	.018	5.0 (1.8, 8.3)*
Body mass index at 25 years of age, kg/m ² (mean ± SD)	23.1 ± 2.7 _a	22.7 ± 2.5 _b	22.6 ± 2.4 _b	22.9 ± 2.7 _b	.011	-0.2 (-0.5, 0.2)
Body mass index at baseline, kg/m ² (mean ± SD)	25.7 ± 2.7 _a	24.8 ± 2.4 _b	24.3 ± 2.5 _c	24.6 ± 3.2 _{b,c}	<.001	0.2 (-0.6, 0.2)
Age started smoking, y (mean ± SD)	18.7 ± 4.7 _a	18.7 ± 4.4 _a	18.3 ± 3.7 _a	17.6 ± 3.7 _b	<.001	1.1 (0.6, 1.6)*
No. of cigarettes per day (mean ± SD)	24.2 ± 13.5 _a	23.0 ± 14.0 _a	24.3 ± 12.6 _a	26.6 ± 11.7 _b	.014	-3.6 (-5.1, -1.9)*
Alcohol consumption, drinks per month (mean ± SD)						
Beer	24.5 ± 34.3 _a	23.0 ± 34.3 _a	25.5 ± 36.1 _a	27.0 ± 38.1 _a	NS	-4.0 (-9.4, 1.4)
Wine	2.3 ± 5.4 _a	2.8 ± 7.7 _a	2.1 ± 6.5 _a	3.0 ± 9.7 _a	NS	-0.2 (-1.4, 1.1)
Liquor	22.4 ± 38.5 _a	20.6 ± 33.5 _a	19.7 ± 33.0 _a	19.3 ± 33.9 _a	NS	1.3 (-3.8, 6.5)
Physical activity, rank (mean ± SD)	3.5 ± 1.5 _{a,b}	3.7 ± 1.5 _a	3.7 ± 1.4 _a	3.3 ± 1.6 _b	<.001	0.4 (0.2, 0.6)*
Coffee, cups per day (mean ± SD)	3.7 ± 2.3 _a	3.8 ± 2.2 _a	4.2 ± 2.4 _b	4.3 ± 2.5 _b	<.001	-0.5 (-0.8, -0.1)*
Pastries, frequency per day (mean ± SD)	1.5 ± 0.6 _{a,b}	1.6 ± 0.7 _a	1.6 ± 0.7 _a	1.4 ± 0.6 _b	.036	0.2 (0.03, 0.22)*
Candy, frequency per day (mean ± SD)	1.2 ± 0.6 _a	1.2 ± 0.5 _a	1.2 ± 0.5 _a	1.2 ± 0.5 _a	NS	0.0 (-0.1, 0.1)
Diet to keep weight low, %	30 _a	21 _b	22 _b	27 _{a,b}	.008	0.8 (0.6, 1.1)

Note. Values with the same subscript are not significantly different from each other at the .05 significance level. CI = confidence interval.

^aFor continuous variables, mean comparison of values of stable weight gainers minus those of super-gainers; for the categorical variable, mean comparison of value of stable gainers divided by that of super-gainers.

*Significantly different at the .05 level (controlling for the Type I multiple comparison error rate).

Effects of Smoking Status on Weight Gain

As can be seen in Table 1, 52% of quitters gained more than 2.3 kg, in comparison with 34% and 35%, respectively, of continuing nonsmokers and continuing smokers. Among quitters, 15% lost weight and 13% gained 11.3 kg or more. Among continuing nonsmokers and smokers, respectively, 21% and 23% lost weight and 4% and 6% gained 11.3 kg or more over the follow-up. Thus, the group of subjects who quit included a higher percentage of super-gainers and a lower percentage who lost weight than either continuing smokers or nonsmokers. The association between weight change and change in smoking status was highly significant, $\chi^2(6) = 253.5, P < .001$.

Characteristics and Behaviors Related to Subsequent Weight Gain

Table 2 presents baseline characteristics for the four weight change groups along with the results from the Duncan multiple comparison test. Confidence intervals for the contrast between super-

gainers and those with stable weight are presented in the far right-hand column. Super-gainers were younger (45.9 vs 46.5 years), were of lower socioeconomic status (a rank of 66.2 vs 71.2), started smoking at a younger age (17.6 vs 18.7 years), were heavier smokers (26.6 vs 23.0 cigarettes per day), exercised less strenuously (a rank of 3.3 vs 3.7), drank more coffee (4.3 vs 3.8 cups per day), and ate fewer pastries (1.5 vs 1.6 pastries per day). No differences between those who reported stable weight and super-gainers were observed for body mass index at 25 years of age (22.9 vs 22.7 kg/m²) or at baseline (24.6 vs 24.8 kg/m²), the number of different alcoholic drinks per month, or the likelihood of dieting to keep weight low.

Table 3 presents selected demographics at follow-up, health status indicators, and change in health habits and dieting history concurrent with weight change over the course of follow-up. Confidence intervals for the contrast between super-gainers and those with stable weight are presented in the far right-hand column.

Super-gainers were more likely to be single (15% vs 10%) than those who reported a stable weight. They also were twice as likely to report having to diet to keep weight low at follow-up (53% vs 28%, in comparison with 27% vs 21% at baseline). Whereas super-gainers reported a smaller increase in wine consumption (3.3 vs 6.2 drinks per month) than did those with stable weight over the course of follow-up, they reported a larger increase in liquor (15.2 vs 7.9 drinks per month) and candy consumption (0.1 vs 0.0 pieces per day) from baseline to follow-up. No significant differences in retirement status, the presence of cardiovascular disease, or change in beer, coffee, and pastry consumption were observed.

Twin Concordance for Weight Change after Smoking Cessation

In this analysis, the twinning condition was used to examine twin pair similarity in weight change in the subset of 146 monozygotic co-twins and 111 dizygotic co-twins in which both members had quit smoking during follow-up. Among

TABLE 3—Subjects' Demographics and Health Status at Follow-Up and Changes in Behaviors from Baseline (1967 through 1969) to Follow-Up (1983 through 1985), by Weight Gain Category

Characteristic	Lost Weight	Stable Weight	Gainers	Super-Gainers	Overall Significance	Comparison between Stable Weight Gainers and Super-Gainers ^a (95% CI)
Marital status, % single	17 _b	10 _a	10 _a	15 _b	.001	0.7 (0.4, 0.9)*
Retired, %	64 _a	50 _b	50 _b	51 _b	< .001	1.0 (0.8, 1.4)
Cardiovascular disease, %	23 _a	14 _b	15 _b	15 _b	< .002	0.9 (0.7, 1.5)
Diet to keep weight low, %	34 _b	28 _c	38 _b	53 _a	< .001	0.5 (0.3, 0.5)*
Change (mean ± SD)						
Beer, drinks per month	-3.3 ± 35.1 _a	-0.5 ± 31.0 _a	0.9 ± 30.9 _a	0.7 ± 32.3 _a	NS	-1.2 (-5.1, 2.7)
Wine, drinks per month	7.9 ± 13.2_a	6.2 ± 10.7_a	7.0 ± 12.3_a	3.3 ± 12.8 _b	< .001	2.9 (1.5, 4.3)*
Liquor, drinks per month	3.4 ± 39.6 _c	7.8 ± 33.2_{b,c}	9.5 ± 34.4_b	15.2 ± 37.4_a	< .001	-7.4 (-11.0, -3.1)*
Coffee, cups per day	-1.0 ± 2.5 _{a,b}	-0.8 ± 2.3 _b	-1.1 ± 2.3 _{a,b}	-1.3 ± 2.4 _a	.02	0.5 (0.2, 0.8)*
Pastries, frequency per day	-0.2 ± 0.7_a	-0.2 ± 0.7_a	-0.2 ± 0.7_a	-0.2 ± 0.7_a	NS	0.0 (-0.1, 0.1)
Candy, frequency per day	-0.1 ± 0.7 _b	0.0 ± 0.6 _b	0.0 ± 0.5 _b	0.1 ± 0.6_a	.01	-0.1 (-0.2, -0.02)*

Note. Values with the same subscript are not significantly different from each other at the .05 significance level. Mean values in boldface indicate that change was significantly different from zero at the .05 significance level. CI = confidence interval.

^aFor categorical variables, mean comparison of values of stable weight gainers divided by those of super-gainers; for continuous variables, mean comparison of values of stable gainers minus those of super-gainers.

*Significantly different at the .05 level (controlling for the Type I multiple comparison error rate).

these groups, 56 monozygotic pairs and 34 dizygotic pairs reported a gain in weight of at least 2.3 kg, and 41 monozygotic pairs and 21 dizygotic pairs reported a loss in weight of more than 2.3 kg. The remaining 49 monozygotic and 56 dizygotic twin pairs were classified as discordant for weight gain or loss. The pairwise concordance rates for weight gain were 53% in monozygotic twin pairs and 38% in dizygotic pairs. Expected rates resulting from chance alone were 30% and 31%, respectively. The difference between the two observed rates for weight gain was statistically significant (mean difference in concordance rates = 0.15; 95% CI = 0.03, 0.26). Similarly, pairwise concordance rates for weight loss were 46% in monozygotic twin pairs and 27% in dizygotic twin pairs. Expected values from chance alone were 20% and 19%, respectively. The difference between the observed rates for weight loss was also statistically significant (mean difference = 0.19; 95% CI = 0.08, 0.30).

Discussion

The average amount of weight gain reported by the ex-smokers in this study was 3.5 kg; 13% of the ex-smokers reported a weight gain of 11.3 kg or more. These figures are similar to those from the Williamson et al.⁶ study, which found an average unadjusted weight gain of 3.1 kg in quitters who had refrained from smok-

ing for more than 1 year over a shorter follow-up interval than the one reported here (10 years vs 16 years) and a comparable percentage of men with excessive weight gain (9.8%). The sample of quitters in the present cohort was similar to the group of sustained quitters in the Williamson et al. study with respect to average age (46.3 vs 47.6 years) and body mass index (24.7 vs 25.7). With regard to the number of cigarettes smoked daily at baseline, our sample of quitters included a greater number of heavy smokers; 44% smoked 25 or more cigarettes per day, in comparison with 33% in the Williamson et al. study.

Among the baseline characteristics associated with excessive weight gain were younger age and heavier smoking. These results are also consistent with the findings of Williamson et al.⁶ Findings from both studies suggest a dose effect for nicotine, with heavier smokers experiencing a larger rebound in weight with the long-term elimination of nicotine. Unlike the Williamson et al. study, however, we did not observe super-gainers to be less obese at baseline than their counterparts with no weight change.

The occurrence of postcessation weight gain in most quitters is thought to result from a transient perturbation of the energy balance equation in which energy input (e.g., caloric intake) is in disequilibrium with energy expended (e.g., physical activity, resting metabolic rate).^{1,5} For

super-gainers, there must therefore be a comparatively larger disruption of the energy equation. Below we offer some possible explanations for this puzzling phenomenon.

First, relative to those with stable weight, it is possible that super-gainers have already adopted health habits, such as exercising less strenuously, that set the stage for reduced energy expenditure after smoking cessation. Second, because they are more likely to be single, this group may also tend to gain more weight because of a lack of social influence from a spouse to manage their caloric intake and to be more weight conscious. Third, the analysis of change in various health habits over the course of follow-up revealed an increase in liquor consumption among quitters who were super-gainers. The increase in total drinks of liquor per month experienced by super-gainers (15.2) was nearly double that of quitters who showed no weight change (7.9). A recent analysis of the relationship between smoking cessation and liquor consumption revealed that, for the entire sample of quitters in the National Academy of Sciences-National Research Council registry (regardless of weight change category), liquor consumption increased by an average of 8.5 drinks per month.¹⁶ The large increase in consumption in super-gainers suggests the possibility of an especially strong compensatory mechanism, with alcohol playing a central role in

replacing the effects of nicotine at either the neural-genetic¹⁷⁻¹⁹ or the behavioral level.²⁰ The compensatory increase in liquor consumption could then alter the energy equation through an increase in total caloric intake.²¹ Although the role of alcohol in body weight in nonalcoholic drinkers remains inconclusive, the few prospective studies conducted to date have found that increased alcohol consumption is associated with an increase in body weight.²²

Contrary to expectations based on the hypothesized disruption in the energy balance equation produced by smoking cessation, there was a subgroup of ex-smokers who reported losing weight over the course of follow-up. In comparison with ex-smokers in the other weight change categories, this group of ex-smokers was older at baseline, reported a higher body mass index at 25 years of age and at the baseline survey, and was more likely to be retired and to report having cardiovascular disease at follow-up. We speculate that, in this group of older quitters, the longer history of obesity and the effects of smoking may have combined to produce a greater prevalence of disease at follow-up. The observed weight loss could result either from the combined effects of aging and disease or from these individuals' effort to reduce risk for progression of disease by losing weight in accordance with advice from their physician.

The concordance analysis also implicates hereditary factors in weight change after smoking cessation. This finding is consistent with our previous analysis showing convergence for weight gain in twins who were initially discordant for smoking status but who then became concordant for nonsmoking status (i.e., the formerly smoking twin gained weight to a level similar to that of his nonsmoking twin).²³ The contribution of new genetic factors to obesity in middle age in this cohort of twins has also been recently demonstrated.²⁴ Given the mean age of the present cohort at baseline (46.3 years), it is possible that smoking cessation coincided with the onset of these effects. In this scenario, the coincident cessation of smoking amplifies the expression of the obesity genes, resulting in a larger than usual disruption of the energy balance equation.

Although this study examined excessive weight gain in the largest sample of quitters followed for the longest interval reported to date, generalizability is limited by the fact that all data were based on

self-report of smoking status and weight in men. Very little is known about the predictors of excessive weight gain or the extent to which genetic factors play a role in weight gain after smoking cessation in women. Because reasons for quitting, age at time of smoking cessation, and duration of smoking cessation were not assessed in this study, we are unable to account for the extent to which these variables mediated the magnitude of the weight gain experienced by the quitters. It is plausible, for example, that individuals who were abstinent longer had gained more weight at follow-up. Finally, although short-term studies indicate that weight gain after cessation reaches a plateau at about 6 months,²⁵ future longitudinal studies could shed further light on the overall shape of the weight gain curve of super-gainers. Is it monotonic, steadily increasing over time, or is it discontinuous, characterized by a sudden, large increase in weight? The answer may shed light on possible mechanisms and on the appropriate timing of interventions to prevent the occurrence of excessive weight gain in smokers who quit. □

Acknowledgments

This research was supported by National Institute on Alcohol Abuse and Alcoholism grant AA08925; National Heart, Lung, and Blood Institute grant HL46115; and National Heart, Lung, and Blood Institute contract 4504-9.

We wish to thank Dennis Robinette, PhD, deceased, for his efforts on behalf of this project. Dr Robinette was with the Medical Research Follow-up Agency, National Academy of Sciences.

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