Relation between changes in intakes of dietary fiber and grain products and changes in weight and development of obesity among middle-aged women[1–3]

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ABSTRACT

Background: Although increased consumption of dietary fiber and grain products is widely recommended to maintain healthy body weight, little is known about the relation of whole grains to body weight and long-term weight changes.

Objective: We examined the associations between the intakes of dietary fiber and whole- or refined-grain products and weight gain over time.

Design: In a prospective cohort study, 74 091 US female nurses, aged 38–63 y in 1984 and free of known cardiovascular disease, cancer, and diabetes at baseline, were followed from 1984 to 1996; their dietary habits were assessed in 1984, 1986, 1990, and 1994 with validated food-frequency questionnaires. Using multiple models to adjust for covariates, we calculated average weight, body mass index (BMI; in kg/m^2), long-term weight changes, and the odds ratio of developing obesity (BMI $\geq$ 30) according to change in dietary intake.

Results: Women who consumed more whole grains consistently weighed less than did women who consumed less whole grains (P for trend < 0.0001). Over 12 y, those with the greatest increase in intake of dietary fiber gained an average of 1.52 kg less than did those with the smallest increase in intake of dietary fiber (P for trend < 0.0001) independent of body weight at baseline, age, and changes in covariate status. Women in the highest quintile of dietary fiber intake had a 49% lower risk of major weight gain than did women in the highest quintile (OR = 0.51; 95% CI: 0.39, 0.67; $P < 0.0001$ for trend).

Conclusion: Weight gain was inversely associated with the intake of high-fiber, whole-grain foods but positively related to the intake of refined-grain foods, which indicated the importance of distinguishing whole-grain products from refined-grain products to aid in weight control. *Am J Clin Nutr* 2003;78:920–7.

KEY WORDS Whole grains, refined grains, dietary fiber, body weight, prospective study, obesity, weight gain, women

INTRODUCTION

According to the third National Health and Nutrition Examination Survey (NHANES III), which ended in 1994, nearly 100 million US adults were overweight or obese (1), which puts them at increased risk of hypertension, dyslipidemia, type 2 diabetes, heart disease, and many other chronic disorders (2). Weight control is clearly an important goal for many US adults. At any given time in the United States, ≈44% of women and 29% of men report that they are attempting to lose weight, and ≈5 million of these adults have used prescription drugs for treatment of obesity (3, 4). Despite the public's increased awareness of the health hazards associated with overweight and obesity, recent reports from the Centers for Disease Control and Prevention indicate that the prevalence of overweight and obesity in the United States continues to increase (5, 6).

At both individual and population levels, strategies that improve nutrition and increase physical activity are fundamental to the control of the epidemic of overweight and obesity (2, 7). Yet the long-term efficacy of any specific dietary approach to weight control remains to be determined (8–10). Because of the belief that diets rich in fiber are generally low in saturated fat, many national authorities have long recommended greater consumption of grain products to control weight (11–14). Whole grains may have beneficial effects on weight control through promoting satiety (15–17). The intake of whole grains may also slow starch digestion or absorption, which leads to

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relatively lower insulin and glucose responses that favor the oxidation and lipolysis of fat rather than its storage (15–17). However, most grain products consumed in the United States are highly refined (17, 18). Refined-grain products have a higher starch content but a lower fiber content (ie, greater energy density) than do whole grains. Concentrations of vitamins, minerals, essential fatty acids, and phytochemicals that are important in carbohydrate metabolism are also lower in refined grains (19).

Indirect evidence from both epidemiologic and short-term experimental studies suggests a beneficial role of a high-fiber diet in weight control (19–21). However, few trials have examined directly the effects of whole grains, as opposed to those of refined grains, on body weight and weight changes. Nor is there any large prospective epidemiologic study directly linking the intake of whole grains to changes in weight over time. To examine further the associations between grain intake and body weight and weight changes, we analyzed prospective data from the Nurses' Health Study (NHS) from 1984 to 1996 using repeated measurements of grain intake and body weight.

SUBJECTS AND METHODS

Study population

The NHS was initiated in 1976 when 121 700 female registered nurses aged 30–55 y answered a mailed questionnaire on their medical history and lifestyle. The cohort has been followed every 2 y since 1976 to ascertain exposures and incident diseases. In 1980, we assessed diet with a 61-item semiquantitative food-frequency questionnaire (FFQ) (22). The subjects who did not satisfy the a priori criterion of reported daily energy intake between 2514 KJ (600 kcal) and 14 665 KJ (3500 kcal) were excluded. In 1984 the semiquantitative FFQ was expanded to include 126 items. Because the expanded questionnaire contained additional food items that are important in assessments of the details of carbohydrate intake and because it accorded with our previous studies in this area, we considered 1984 as the baseline for the analytic cohort of 81 757 women. We further excluded respondents with previously diagnosed diabetes ($n = 2518$); cardiovascular disease (CVD), including angina, myocardial infarction, stroke, and other CVDs ($n = 690$); and cancers ($n = 4458$). The final baseline population consisted of 74 091 women who were 38–63 y old in 1984.

Assessment of whole- and refined-grain consumption

Measurements of whole-grain and refined-grain foods, along with other aspects of diet, were repeated in 1986, 1990, and 1994 using FFQs nearly identical to the questionnaire used in 1984. For each food, a commonly used unit or portion or serving size (eg, 1 slice of bread) was specified, and participants were asked how often, on average, during the previous year they had consumed that amount. Nine responses were possible, ranging from "never" to "≥ 6 times/d." On the basis of the responses to these questions, we calculated the average grain intake (servings/d) for each participant. The type and brand of breakfast cereal also were ascertained. We used a procedure developed by Jacobs et al (23) and Liu et al (24) to classify foods into whole and refined grains. This classification scheme was previously used in this cohort for studying the relations of grain intake to the risk of type 2 diabetes (25) and CVD (24, 26). Specifically, whole-grain foods included dark bread, whole-grain breakfast cereal, popcorn, cooked oatmeal, wheat germ, brown rice, bran, and other grains (eg, bulgur, kasha, couscous). Refined-grain foods included sweet rolls and cakes or desserts, white bread, pasta, English muffins, muffins or biscuits, refined-grain breakfast cereal, white rice, pancakes or waffles, and pizza. The list of breakfast cereals reported in the semiquantitative FFQ was evaluated for whole-grain and bran content; breakfast cereals with ≥ 25% whole grain or bran content by weight were classified as whole grain. A full description of the semiquantitative FFQs and data on reproducibility and validity in this cohort were published previously (22, 27). The performance of the semiquantitative FFQ in assessing the individual grain products was documented to be high (28). For example, between the FFQ and detailed diet records in a sample of the participants, correlation coefficients were 0.75 for cold breakfast cereal, 0.71 for white bread, and 0.77 for dark bread. Overall, these data indicate that the semiquantitative FFQ provides a reasonably valid measure of average long-term dietary intake.

Measurements of body weight, body mass index, and changes in weight

Participants self-reported their body weight every 2 y from 1984 to 1996. Height was reported in 1976. In this cohort, body mass index (BMI; in kg/m^2) is minimally correlated with height ($r = -0.03$) and highly correlated with height-adjusted fat mass measured by underwater weighing of young and middle-aged women ($r = 0.8–0.9$) (29). We calculated weight changes from 2–4-y intervals between 1984 and 1996 as well as from 1984 to 1996. In a sample of 184 participants described previously (30), the correlation between self-reported and directly measured weight was 0.96.

Statistical analysis

We first conducted a cross-sectional analysis of the associations between baseline covariates and the intakes of whole grains and refined grains in 1984. Unless otherwise indicated, intake of whole or refined grains was categorized into quintiles, and we calculated mean body weight and BMI according to these quintiles. We then plotted the mean attained BMI according to the intake of whole or refined grains at each 2-y interval from 1984 to 1996. Second, we used generalized estimating equations to examine the direct relation between changes in intake of whole or refined grains in relation to changes in weight in the same period with adjustment for changes in covariates. Changes in weight were defined as the difference between weight assessed in each dietary period (1984–1986, 1986–1990, and 1990–1994). Covariates, including age; years of follow-up; change in exercise (ie, differences in metabolic score); change in smoking status (ie, increase, decrease, no change); change in hormone replacement status status (ie, from current use to no use, same use, from no use to current use); and changes in intakes of alcohol, caffeine, and total energy were defined by taking the differences between 1984 and 1986, between 1986 and 1990, and between 1990 and 1994. Because exercise status was not assessed in 1984, we carried forward information from 1982. Tests of linear trend across increasing categories of changes in grain consumption were conducted by treating the

median of intake in categories (servings/d) as a continuous variable. The model has the following form:

$$Y_{it} = X^{T}_{it}\beta + \varepsilon_{it} \quad (1)$$

where Y_{it} represents the outcome, either changes in BMI or changes in weight ($Y_{it} = \text{BMI}_t - \text{BMI}_{t-1}$ or $\text{weight}_t - \text{weight}_{t-1}$), for the individual i; and X^{T} is a vector of covariates, including changes in grain intake from time $t-1$ to t for the individual i. In estimating the population-average change in body weight associated with change in grain intake, we used the robust variance to ensure valid inference in these models (31). To understand the weight changes over time in relation to changes in grain intake, we calculated the multivariate-adjusted mean change in BMI or mean change in weight from 1984 to 1996 associated with changes in intake from 1984 to 1994, adjusting for changes in covariates in the same time period. On the basis of validation data from 1980 and 1986 obtained in a subsample of 92 nurses, we used a two-step process known as regression calibration to calculate an estimate of deattenuated effect of change in dietary fiber intake on weight change. Details of this method for cross-sectional data were described previously (27, 32). [Readers may contact SL for information on the extension of this method to longitudinal data.]

In some analyses, we adjusted for baseline covariate status rather than for changes in covariate status, and the results were similar to those with the adjustment for covariate status. To examine whether the relations between grain intake and BMI differ by BMI at baseline, we conducted stratified analyses using the BMI in 1984 (BMI $\geq$ 25 compared with BMI $<$ 25).

Finally, to understand further the relation of grain intake to the risk of obesity and major weight gain, we categorized participants into 2 categories of BMI (BMI $\geq$ 30 and BMI $<$ 30) or 2 categories of weight gain (changes in weight $\geq$ 25 kg and changes in weight $<$ 25 kg) and estimated the odds ratios for each quintile of changes in grain intake (from the smallest increase in intake to the largest increase in intake). All analyses were conducted with the use of SAS software (version 8; SAS Institute Inc, Cary, NC). All P values were two-sided.

TABLE 1
Age-standardized baseline distributions of covariates according to quintiles (Q) of intake of whole or refined grains among 74,091 US female nurses aged 38–63 y in 1984[1]

	Whole-grain intake[2]			Refined-grain intake		
Variables	Q1 (n = 14 819)	Q3 (n = 14 821)	Q5 (n = 14 819)	Q1 (n = 14 817)	Q3 (n = 14 817)	Q5 (n = 14 818)
Current smoker (%)	35	23	16	24	24	25
Premenopausal (%)	51	48	46	34	49	51
Current use of hormone replacement therapy (%)	8	11	15	15	11	9
Hypertension (%)	21	20	21	24	20	19
Hypercholesterolemia (%)	7	7	11	10	8	7
Age (y)	50 ± 7[3]	50 ± 7	50 ± 7	50 ± 7	50 ± 7	50 ± 7
BMI (kg/m^2)[4]	24.9 ± 5	24.9 ± 5	24.5 ± 4	24.6 ± 4	24.9 ± 5	25.2 ± 5
Weight at baseline (kg)[4]	67.0 ± 14	67.3 ± 13	66.1 ± 12	66.4 ± 13	67.0 ± 13	67.6 ± 13
Weight at age 18 y (kg)	56.8 ± 9	57.3 ± 9	57.5 ± 9	57.7 ± 9	57.2 ± 9	57.0 ± 9
Metabolic score/wk[5]	12 ± 3	14 ± 4	16 ± 5	17 ± 5	14 ± 4	12 ± 3
Total caloric intake (kcal)	1694 ± 534	1808 ± 534	1740 ± 514	1604 ± 504	1737 ± 509	1891 ± 541
Carbohydrate (g/d)	178 ± 35	183 ± 29	197 ± 30	182 ± 40	185 ± 29	191 ± 26
Glycemic load (g/d)	136 ± 32	139 ± 26	151 ± 27	134 ± 35	141 ± 26	151 ± 23
Glycemic index	76 ± 6	76 ± 5	75 ± 5	73 ± 7	76 ± 5	79 ± 4
Protein (g/d)	68 ± 14	72 ± 12	73 ± 13	77 ± 15	71 ± 12	66 ± 11
Polyunsaturated fat (g/d)	12 ± 3	12 ± 3	12 ± 3	11 ± 4	12 ± 3	12 ± 3
Monounsaturated fat (g/d)	24 ± 5	23 ± 4	21 ± 4	21 ± 5	23 ± 4	23 ± 4
Saturated fat (g/d)	24 ± 5	22 ± 4	20 ± 4	21 ± 5	22 ± 4	22 ± 4
trans Fatty acids (g/d)	4 ± 1	3 ± 1	3 ± 1	3 ± 1	3 ± 1	4 ± 1
Cholesterol (mg/d)	292 ± 110	290 ± 89	268 ± 97	296 ± 123	287 ± 85	269 ± 85
Fruit and vegetables (servings/d)	4.7 ± 2.5	5.9 ± 2.8	6.4 ± 3.0	6.6 ± 3.4	5.7 ± 2.7	4.8 ± 2.3
Dietary fiber (g/d)	13 ± 4	16 ± 4	20 ± 5	18 ± 6	16 ± 4	15 ± 4
Caffeine (mg/d)	346 ± 247	318 ± 227	287 ± 226	306 ± 245	317 ± 229	328 ± 227
Alcohol (g/d)	8 ± 13	7 ± 11	7 ± 11	10 ± 15	7 ± 10	5 ± 8

[1] Median intakes (servings · 1000 kcal^{-1} · d^{-1}) of whole-grain and refined-grain foods: Q1, 0.07 and 0.40, respectively; Q3, 0.48 and 1.05; Q5, 1.62 and 2.27. Because of the larger number of subjects, all P values for age-adjusted differences in covariates across categories of grain intake were $<$ 0.05 except for the relation between polyunsaturated fat and whole grain.

[2] Whole grain includes dark bread, whole-grain breakfast cereal, popcorn, cooked oatmeal, wheat germ, brown rice, bran, and other grains (eg, bulgur, kasha, couscous). Breakfast cereals with $\geq$ 25% whole-grain or bran content by weight were classified as whole grain.

[3] $\bar{x}$ ± SD.

[4] In 1984.

[5] $\bar{x}$.

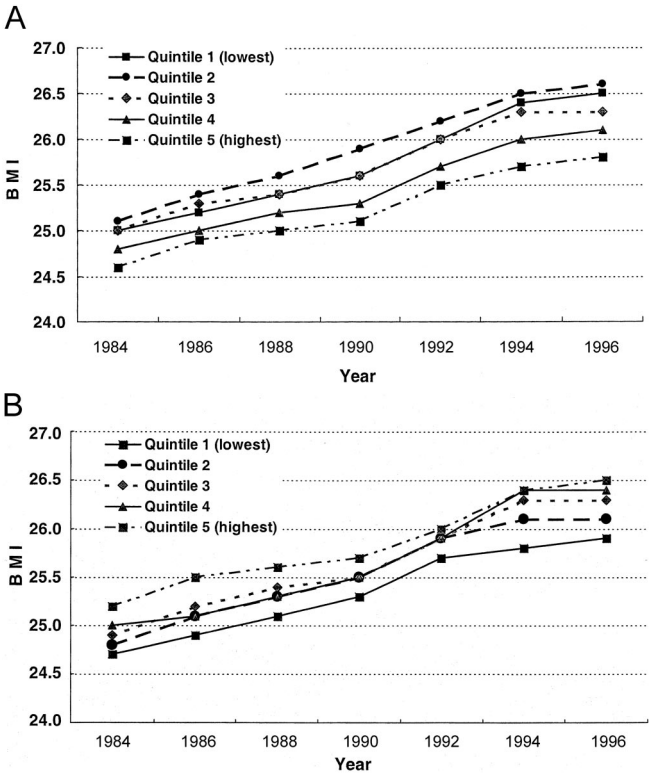

FIGURE 1. A: Mean BMI from 1984 to 1996 according to quintiles of whole-grain intake. BMI differences by quintiles of intake, $P < 0.0001$. Whole-grain intake × years of follow-up interaction, $P = 0.02$. B: Mean BMI from 1984 to 1996 according to quintiles of refined grain intake. BMI differences by quintiles of intake, $P < 0.0001$. Refined-grain intake × years of follow-up interaction, $P = 0.01$.

RESULTS

The median intake of energy-adjusted whole grain ranged from virtually no consumption in the lowest quintile to 1.62 servings · 1000 $kcal^{-1} \cdot d^{-1}$ in the highest quintile (**Table 1**). Women with high intake of whole grains smoked less, exercised more, and were more likely to use postmenopausal hormones. Greater whole-grain intake was also associated with higher intakes of carbohydrate, protein, dietary fiber, and fruit and vegetables but with lower intakes of fats, cholesterol, and alcohol. These baseline associations were generally the opposite for women with greater intake of refined-grain products.

At baseline in 1984, women in the highest quintile of whole-grain intake weighed ≈0.9 kg less than did women in the lowest quintile of intake (BMI of 24.5 compared with BMI of 24.9; P for trend < 0.0001) (**Figure 1**A), whereas women in the highest quintile of refined-grain intake weighed ≈1.2 kg more than did women in the lowest quintile of intake (BMI of 25.2 compared with BMI of 24.6; P for trend < 0.0001) (Figure 1B). During a 10-y period from 1984 to 1994, the mean daily intakes of whole grain increased from 0.64 servings per 1000 kcal to 0.77 servings per 1000 kcal. The correlation coefficients between any 2 assessments of whole-grain intake ranged from 0.46 to 0.67, depending on the closeness in time. Although BMI was inversely associated with whole-grain intake and positively associated with refined-grain intake, average BMI increased with time regardless of levels of grain intake (Figure 1).

Changes in the intakes of whole grains, refined grains, or dietary fiber in relation to average changes in weight or BMI in 2–4-y intervals (between 2 dietary assessments) are shown in **Table 2**. In general, increases in the intake of whole grains were associated with less weight gain (mean weight gain of 1.58 kg in 2–4 y in the lowest quintile and of 1.07 kg in the highest quintile; P for trend < 0.0001). In contrast, increases in the intake of refined grains were related to greater weight gain (from 0.99 kg to 1.65 kg; P for trend < 0.0001). Similarly, greater increases in dietary fiber intake were associated with less weight gain every 2–4 y.

We observed similar patterns when we examined changes in grain intake from 1984 to 1994 in relation to the multivariate-adjusted mean long-term weight changes from 1984 to 1996. As shown in **Table 3**, over the entire follow-up period, an increased intake of dietary fiber and whole grains was associated with significantly less weight gain, whereas the opposite was evident for increased intake of refined grains. Adjustment for total energy intake had little effect on these results. During 12 y of follow-up, those who had the greatest increase in dietary fiber intake gained an average of 1.52 kg less than did those who had the smallest increase in intake (P for trend < 0.0001), independent of body weight at baseline; age; and changes in physical activity, smoking status, alcohol consumption, caffeine intake, and hormone replacement therapy use; and intakes of different types of fats, protein, and total energy. After further correction for measurement errors in change in dietary fiber intake, we estimated that an increase of 12 g in dietary fiber intake was associated with ≈3.5 kg (8 lb) less weight gain in 12 y. Overall, women who consumed a larger amount of whole grains consistently weighed less in each interval than did those who consumed a smaller amount of whole grains; in contrast, women who consumed a larger amount of refined grains consistently weighed more than did those who consumed a smaller amount of refined grains ($P < 0.0001$).

The relations between intake of high-fiber whole-grain foods and weight change also appeared to differ by BMI status at baseline ($P < 0.0001$ for interaction; **Figure 2**). Specifically, the beneficial effects of an increased intake of dietary fiber on weight gain were greater among those who were overweight at baseline. Among this overweight group, those in the highest quintile of intake experienced only about one-half (2.65 kg) as much weight gain as did those in the lowest quintile of intake (5.10 kg) during the entire follow-up period (P for trend < 0.0001).

To examine further the association between grain intake and major weight gain and the development of obesity, we calculated odds ratios for obesity (BMI ≥ 30) and for major weight gain (≥ 25 kg) in 12 y according to changes in intake in the same period. During the 12-y follow-up, 6400 women became obese and 657 had a major weight gain (**Table 4**). The odds of developing obesity or having a major weight gain were generally lower with larger intakes of dietary fiber and whole grains but not with a larger intake of refined grains. Compared with women who were in the lowest quintile of fiber intake, women who increased their intake of dietary fiber to the highest quintile reduced their risk of major weight gain by 49% (OR = 0.51; 95% CI: 0.39, 0.67; $P < 0.0001$ for trend).

TABLE 2
Change in BMI or in weight according to quintiles (Q) of change in intakes of whole or refined grains in the Nurses' Health Study from 1984 to 1996[1]

	Changes in intake by quintile										
	Average changes in BMI in 2–4 y						Average change in weight in 2–4 y					
	Q1	Q2	Q3	Q4	Q5	*P* for trend	Q1	Q2	Q3	Q4	Q5	*P* for trend
Whole-grain intake												
Model 1[2]	0.59 ± 0.01	0.54 ± 0.01	0.52 ± 0.01	0.49 ± 0.01	0.39 ± 0.01	< 0.0001	1.58 ± 0.02	1.45 ± 0.02	1.39 ± 0.03	1.32 ± 0.02	1.07 ± 0.02	< 0.0001
Model 2[3]	0.56 ± 0.01	0.52 ± 0.01	0.49 ± 0.01	0.52 ± 0.01	0.46 ± 0.01	< 0.0001	1.52 ± 0.02	1.41 ± 0.02	1.31 ± 0.03	1.40 ± 0.02	1.23 ± 0.02	< 0.0001
Refined-grain intake												
Model 1[2]	0.37 ± 0.01	0.45 ± 0.01	0.51 ± 0.01	0.58 ± 0.01	0.62 ± 0.01	< 0.0001	0.99 ± 0.03	1.21 ± 0.03	1.37 ± 0.02	1.55 ± 0.02	1.65 ± 0.03	< 0.0001
Model 2[3]	0.42 ± 0.01	0.47 ± 0.01	0.52 ± 0.01	0.56 ± 0.01	0.57 ± 0.01	< 0.0001	1.14 ± 0.03	1.28 ± 0.02	1.39 ± 0.02	1.53 ± 0.02	1.57 ± 0.03	< 0.0001
Intake of dietary fiber												
Model 1[2]	0.69 ± 0.01	0.57 ± 0.01	0.53 ± 0.01	0.46 ± 0.01	0.29 ± 0.01	< 0.0001	1.87 ± 0.02	1.53 ± 0.03	1.42 ± 0.02	1.25 ± 0.02	0.77 ± 0.02	< 0.0001
Model 2[3]	0.64 ± 0.01	0.56 ± 0.01	0.51 ± 0.01	0.49 ± 0.01	0.36 ± 0.01	< 0.0001	1.73 ± 0.02	1.5 ± 0.03	1.37 ± 0.02	1.34 ± 0.02	0.97 ± 0.02	< 0.0001

[1] $\bar{x}$ ± SE. Q1 included those who had the smallest increase or decrease in intake from 1984 to 1994, whereas Q5 included those who had the largest increase in intake from 1984 to 1994.
[2] $\bar{x}$ weight gain (in kg) from 1984 to 1996 was estimated by model 1 with adjustment for age.
[3] Adjusted for age; changes in exercise (differences in metabolic score); change in smoking status (ie, increase, decrease, no change); change in hormone replacement therapy status (ie, increase, decrease, no change); changes in intakes of alcohol, caffeine, and total energy; changes in intakes of saturated fat, polyunsaturated fat, monounsaturated fat, *trans* fat, and protein; and BMI at baseline.

DISCUSSION

This 12-y prospective study of middle-aged women provides both cross-sectional and longitudinal estimates of the effects of whole or refined grains on body weight and changes in weight. In the cross-sectional analysis at baseline, body weight was inversely associated with whole-grain intake but positively associated with refined-grain intake. Longitudinally, participants who had greater intake of whole grains tended to gain less weight than did those with greater intake of refined grains. Compared with women who had decreased intake of high-fiber or whole-grain products, those who had the greatest increase in intake of high fiber or whole grains had half the odds of becoming obese over a 12-y period.

These findings should be interpreted in the context of the study's strengths and limitations. The NHS data are unique in that multiple measurements of diet and body weight are available, which makes it possible to observe the temporal relation between the intake of whole or refined grains and changes in weight. By using each woman as her own control and directly defining changes in grain intake through multiple assessments of diet, we can estimate the amount of weight change associated with changes in the intake of whole or refined grains.

The observational nature of our study design, however, still hampers straightforward interpretation. First, because both intake of whole grain and body weight are time-dependent variables, we cannot determine with complete certainty that changes in grain intake preceded changes in weight. For example, those who had recently gained weight might, in an attempt to lose weight, increase their intake of grain products. Thus, it is not clear whether increased intake of whole grains prevented weight gain, or whether it is just a marker for attempted weight loss among people with recent weight gain. In addition, the general health consciousness that might be associated with both increased whole-grain intake and caloric restriction remains a potential threat to the validity of our findings. To address this issue, we defined changes in weight as well as changes in grain intake by taking the difference between 2 measurements from 1984 to 1996 and with adjustment for previously attained weight in the model so that any systematic biases due to attained weight could be minimized. However, calculating the differences between 2 dietary assessments would increase measurement error by incorporating errors of both assessments, which suggests that our estimates of the potential effects of dietary fiber or whole grains on weight changes might be conservative.

Further complicating the picture is the possibility not only that BMI can change in response to diet but also that attained BMI may lead both to real changes in diet and to changes in self-reporting of diet (ie, a misclassification of dietary intake that is dependent on body weight). For example, it has been reported that those who are obese are more likely to underreport their energy intake, which makes the study of diet and obesity in an observational setting difficult (33–35). However, assessment of whole- grain foods with the questionnaires used in this study had relatively high validity ($r > 0.70$ compared with dietary record for most whole-grain foods). In multivariate analyses, we adjusted for many potential predictors of underreporting, including age, smoking, physical inactivity, and other known predictors of weight gain, that might minimize this bias. Moreover, results from these multivariate anal-

TABLE 3
Average weight gain (in kg) according to quintiles (Q) of change in intake in the Nurses' Health Study from 1984 to 1996

	Changes in intake by quintile					
	Q1	Q2	Q3	Q4	Q5	*P* for trend
Whole grain						
Median (servings · 1000 kcal^{-1} · d^{-1})	−0.59	−0.09	0.11	0.38	0.90	
Model 1[1]	4.58 ± 0.10[2]	4.23 ± 0.09	4.4 ± 0.09	4.32 ± 0.09	4.07 ± 0.09	< 0.0001
Model 2[3]	4.51 ± 0.10	4.35 ± 0.09	4.60 ± 0.09	4.45 ± 0.09	4.12 ± 0.09	< 0.0001
Refined grain						
Median (servings · 1000 kcal^{-1} · d^{-1})	−0.91	−0.29	0.02	0.32	0.86	
Model 1[1]	3.94 ± 0.09	4.15 ± 0.09	4.34 ± 0.09	4.47 ± 0.09	4.71 ± 0.09	< 0.0001
Model 2[3]	4.25 ± 0.10	4.3 ± 0.09	4.38 ± 0.09	4.44 ± 0.09	4.68 ± 0.09	< 0.0001
Dietary fiber						
Median (g/d)	−3.40	0	2.20	4.60	8.90	
Model 1[1]	5.10 ± 0.09	4.44 ± 0.09	4.24 ± 0.09	4.16 ± 0.09	3.68 ± 0.09	< 0.0001
Model 2[3]	5.16 ± 0.10	4.6 ± 0.09	4.43 ± 0.09	4.26 ± 0.09	3.64 ± 0.09	< 0.0001

[1] Average weight gain (in kg) from 1984 to 1996 was estimated by model 1 with adjustment for age.
[2] $\bar{x}$ ± SE.
[3] Adjusted for age; changes in exercise (differences in metabolic score); change in smoking status (ie, increase, decrease, no change); change in hormone replacement therapy status (ie, increase, decrease, no change); changes in intakes of alcohol, caffeine, and total energy; changes in intakes of saturated fat, polyunsaturated fat, monounsaturated fat, *trans* fat, and protein; and BMI at baseline.

yses showed that weight gain over time was inversely associated with increases in whole-grain intake but positively related to increases in refined-grain intake. Other dietary factors may have accounted for the observed relations between grain intake and body weight. However, the association between the intake of grain products and weight changes remains almost identical when we conducted a series of sensitivity analyses in which the intakes of red meats, fruit and vegetables, and dairy products were simultaneously included in the same model along with whole grains or refined grains (data not shown). The similar magnitudes of associations compared with the age-adjusted analyses and the specific findings regarding the different effects of whole grain versus refined grain intake on weight gain argue against confounding as a full explanation for our findings.

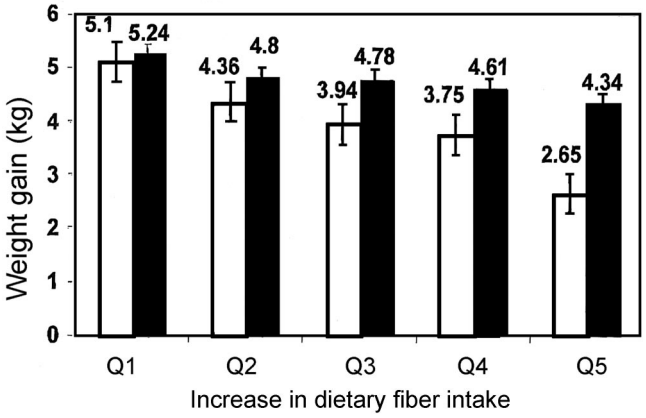

FIGURE 2. Multivariate-adjusted weight gain in kilograms by quintiles (Q) of change in dietary fiber intake from 1984 to 1994 according to BMI in 1984. BMI ≥ 25 (□), *P* for trend < 0.0001; BMI < 25 (■), *P* for trend = 0.01; BMI at baseline × change in fiber intake interaction, *P* < 0.001. Covariates adjusted for were age; changes in exercise (differences in metabolic score); changes in smoking status (ie, increase, decrease, no change); change in hormone replacement therapy status (ie, increase, decrease, no change); changes in intakes of alcohol, caffeine, and total energy; changes in intakes of saturated fat, polyunsaturated fat, monounsaturated fat, *trans* fat, and protein; and BMI at baseline. Median values in each quintile of change in dietary fiber intake (g/d) were −3.4, 0, 2.2, 4.6, and 8.9 for quintiles 1, 2, 3, 4, and 5, respectively.

Diet may affect body weight through multiple pathways, including control of satiety and metabolic efficiency, or through modulation of insulin secretion and action. Total and saturated fats have been the focus of intense scientific scrutiny as potential causes for overweight and obesity, but as yet there is no conclusive evidence directly linking dietary fats to body fat. Whereas there is no doubt that overfeeding animals with a large percentage of energy from fat can cause obesity and insulin resistance (36, 37), the magnitude and long-term significance of the effect of a low-fat diet on weight control in humans remain uncertain (9, 38). In contrast, energy-restricted low-fat diets have been shown to achieve ≤ 10% reduction in weight in many feeding trials (39, 40). But much of the weight thus lost is regained within 12 mo, and no long-term efficacy has ever been convincingly shown (41). Moreover, the effects of changes in dietary composition (percentage of energy from fat rather than from carbohydrates) alone on weight loss appeared minimal (41).

Reports based on NHANES III and a recent time-trend analysis indicate that intakes of both total and saturated fat, in terms of the percentage of total energy intake, have been declining in the United States since 1960s (42, 43). In contrast, in the same period, an increase in the intake of refined carbohydrates in the form of processed grains, soft drinks, sugars, and refined flours in the US food supply has been reported to parallel the increased prevalence of obesity and diabetes (44). Consistent with these reports, our data indicate that the intake of refined grains is directly associated with dietary glycemic load and index, which suggests that an overemphasis on a low-fat diet might have contributed to an increase in intake of high-energy and high-glycemic-load foods. Long-term intervention trials may be necessary if we are to better estimate the relation between changes in the intake of refined grains and weight control, but the feasibility of such long-term trials remain unclear.

TABLE 4
Adjusted relative odds ratios for attained BMI ≥ 30 or major weight gain (≥ 25 kg) in 12 y according to quintiles (Q) of change in grain intake in the Nurses' Health Study from 1984 to 1996

	Change in intake by quintiles											
	Odds ratio for BMI ≥ 30 (n = 6400)						Odds ratio for weight gain ≥ 25 kg (n = 657)					
	Q1	Q2	Q3	Q4	Q5	P for trend	Q1	Q2	Q3	Q4	Q5	P for trend
Whole grain												
Cases (n)	1351	1283	1307	1252	1207		142	143	134	125	113	
Model 1[1]	1.00	0.90 (0.82, 0.97)[2]	0.90 (0.83, 0.98)	0.86 (0.79, 0.93)	0.85 (0.79, 0.93)	0.0002	1.00	0.87 (0.69, 1.11)	0.79 (0.62, 1.00)	0.75 (0.59, 0.96)	0.73 (0.57, 0.94)	0.006
Model 2[3]	1.00	0.85 (0.77, 0.95)	0.87 (0.78, 0.97)	0.82 (0.74, 0.92)	0.81 (0.73, 0.91)	0.0002	1.00	0.96 (0.74, 1.25)	0.97 (0.75, 1.26)	0.83 (0.64, 1.09)	0.77 (0.59, 1.01)	0.03
Refined grain												
Cases (n)	1264	1236	1193	1279	1427		125	115	116	130	171	
Model 1[1]	1.00	0.97 (0.90, 1.06)	0.96 (0.87, 1.03)	1.03 (0.95, 1.12)	1.21 (1.11, 1.31)	< 0.0001	1.00	0.96 (0.75, 1.24)	1.03 (0.80, 1.32)	1.16 (0.91, 1.49)	1.61 (1.27, 2.03)	< 0.0001
Model 2[3]	1.00	0.96 (0.88, 1.05)	0.94 (0.86, 1.03)	1.03 (0.95, 1.13)	1.18 (1.08, 1.28)	< 0.0001	1.00	0.85 (0.64, 1.13)	0.86 (0.65, 1.15)	0.94 (0.72, 1.24)	1.26 (0.97, 1.64)	0.04
Dietary fiber												
Cases (n)	1581	1350	1207	1236	1026		206	132	110	102	107	
Model 1[1]	1.00	0.81 (0.74, 0.87)	0.72 (0.66, 0.78)	0.73 (0.68, 0.79)	0.61 (0.56, 0.66)	< 0.0001	1.00	0.60 (0.48, 0.75)	0.51 (0.40, 0.64)	0.48 (1.38, 0.65)	0.53 (0.42, 0.68)	< 0.0001
Model 2[3]	1.00	0.77 (0.69, 0.86)	0.67 (0.60, 0.74)	0.69 (0.60, 0.77)	0.66 (0.58, 0.74)	< 0.0001	1.00	0.69 (0.54, 0.87)	0.56 (0.43, 0.73)	0.53 (0.41, 0.70)	0.51 (0.39, 0.67)	< 0.0001

[1] Adjusted for age.
[2] 95% CIs in parentheses.
[3] Adjusted for age; changes in exercise (differences in metabolic score); changes in smoking status (ie, increase, decrease, no change); changes in hormone replacement therapy status (ie, increase, decrease, no change); changes in intakes of alcohol, caffeine, and total energy; changes in intakes of saturated fat, polyunsaturated fat, monounsaturated fat, *trans* fat, and protein; and BMI at baseline.

Experimental data indicate that refined-grain products, unlike whole-grain products, can induce an increase in fat synthesis in animal feeding trials even when the total energy intake is unchanged and body weight remains constant (45). Results from several short-term (a single meal or a single day) feeding trials in humans suggest that the consumption of whole-grain products with a low glycemic index might increase satiety and reduce energy consumption and thus contribute to weight loss (20). Our data are consistent with results from these animal and human experiments. In addition, attained body weight may function as an important modifier for the effects of whole grains, as indicated by the observation that the relation between dietary fiber or whole-grain food intake and weight change also appeared to differ by BMI status at baseline (Figure 2). The beneficial effects of increased intake of dietary fiber on weight gain were most significant among subjects who were overweight at baseline. Several epidemiologic studies of dietary fiber also suggest that the intake of whole grains but not of refined grains is inversely associated with body weight and fat distribution (21, 46). The inherent high-fiber content of most whole-grain foods may help prevent weight gain by increasing appetite control through producing a delay in carbohydrate absorption (47). Moreover, multiple enzyme inhibitors that exist in a whole-grains–fiber complex might directly affect metabolic efficiency (19). This mechanism might serve as yet another way whereby whole grains could have beneficial effects on body weight. Finally, high concentrations of insulin associated with low-fiber refined grains may over the long term lead to weight gain by directing metabolic fuels from oxidation to storage.

In conclusion, in this prospective study of apparently healthy middle-aged women, weight gain was inversely associated with increases in the intake of whole grains but positively associated with increases in the intake of refined grains. This suggests the potential importance of increasing the intake of dietary fiber as well as of distinguishing whole-grain from refined-grain products to control weight.

SL participated in the study design, data collection, and data analysis and wrote the first draft of the manuscript. WCW, GC, FBH, JEM, and BR participated in the study design, data collection, and data analysis. The authors had no conflicts of interest.

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