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Relation of Vegetable, Fruit, and Grain Consumption to Colorectal Adenomatous Polyps

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Previous studies suggest that colorectal cancer risk decreases with higher intake of vegetables, fruits, and grains. Few studies, however, have examined these factors in relation to occurrence of colorectal polyps. The authors used case-control data from 488 matched pairs to evaluate associations of vegetables, fruits, and grains with polyps. Subjects were southern Californians aged 50–74 years who had a sigmoidoscopy in 1991–1993. Diet in the year before sigmoidoscopy was measured with a food frequency questionnaire. Frequent consumption of vegetables, fruits, and grains was associated with decreased polyp prevalence. Specifically, the adjusted odds ratio comparing the highest with the lowest quintile of intake for vegetables was 0.47 (95% confidence interval (CI) 0.29–0.76), for fruits was 0.65 (95% CI 0.40–1.05), and for grains was 0.55 (95% CI 0.33–0.91). The authors also found inverse associations for high carotenoid vegetables, cruciferae, high vitamin C fruits, garlic, and tofu (or soybeans). After further adjusting for potentially anticarcinogenic constituents of these foods, high carotenoid vegetables, cruciferous vegetables, garlic, and tofu (or soybeans) remained inversely associated with polyps. These findings support the hypothesis that high intake of vegetables, fruits, or grains decreases the risk of polyps and suggest that any protective effects might reflect unmeasured constituents in these foods. *Am J Epidemiol* 1996;144:1015–25.

case-control studies; cereals; colonic neoplasms; diet; fruit; garlic; vegetables

The role of diet in the etiology of colorectal cancer, the second most common cause of cancer death in the United States (1), remains an area of active investigation. Of all food groups investigated, high vegetable consumption yields the most consistent association with decreased risk of colorectal neoplasia (1–3). Evidence supporting this decreased risk includes results from a few studies of adenomatous polyps (which may progress to colorectal carcinomas) (4). Fruit and grain intake also appears to be inversely related to risk of colorectal cancer (1) and polyps (4), although less consistently than vegetables. These potentially protective associations may result from the high levels of dietary fiber, antioxidants (e.g., beta-carotene, vitamin C), or other anticarcinogenic constituents (e.g., protease inhibitors, phytoestrogens) in these vegetables, fruits, and grains. However, the association of adenomatous polyps of the large bowel with intake of vegetables, fruits, and grains has not been studied to any great degree, and existing data on these associations are not entirely consistent.

Because adenomatous polyps are precursors to colorectal cancer, studying polyps instead of cancer might allow one to measure the diet of relatively asymptomatic subjects closer to the time of the initial neoplastic process. Here, we use data from a sigmoidoscopy-based case-control study to evaluate associations of vegetables, fruits, and grains with the prevalence of adenomatous polyps of the large bowel. We looked at foods 1) to complement other work, looking at nutrient data from this study (5); and 2) because associations with polyps due to unmeasured, unknown, or interacting constituents in food may be missed in an analysis focusing on nutrient effects. Moreover, understanding food effects is important for developing achievable dietary recommendations.

MATERIALS AND METHODS

Subjects were eligible for the study if they underwent a screening sigmoidoscopy at either of two Southern California Kaiser Permanente Medical Centers (i.e., Bellflower or Sunset) from January 1, 1991,

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Abbreviations: CI, confidence interval; OR, odds ratio.

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asymptomatic

through August 25, 1993. Eligible men and women were aged 50–74 years; were free of invasive cancer, inflammatory bowel disease, and familial polyposis; were fluent in English; had no previous bowel surgery; were residents of the Los Angeles region; and had no physical or mental disability precluding an interview. In addition, subjects who had severe gastrointestinal symptoms were excluded. Cases were subjects who had first time diagnoses of one or more histologically confirmed adenomatous polyps. Controls had no polyps of any type at sigmoidoscopy, had no history of polyps, and were individually matched to cases by gender, age (within 5-year category), date of sigmoidoscopy (within 3-month category), and Kaiser center. The study was approved by the Human Subjects Protection Committee of the University of California, Los Angeles, and the Kaiser-Permanente Institutional Review Board.

During the accrual period, we identified 628 cases and 689 controls who were potentially eligible. Of these, 70 cases and 94 controls refused interview, and we were unable to contact 29 cases and 32 controls. Thus, we obtained interview data for 529 cases and 563 controls. The response rate (i.e., number interviewed/number eligible) was 84 percent among cases and 82 percent among controls. If the control initially matched to a case was not interviewed, a replacement control was identified.

Among interviewed subjects, the indications for sigmoidoscopy were "routine" for 45 percent of cases and 44 percent of controls, were referred for specific minor symptoms for 16 percent of cases and 13 percent of controls, and were not given for 39 percent of cases and 43 percent of controls. The average depth of penetration of the flexible sigmoidoscope was 55 cm for cases (standard deviation = 11 cm) and 59 cm for controls (standard deviation = 5 cm). Fifteen cases had carcinoma in situ in addition to adenomatous polyps. The number and size of polyps were indicated on a study form completed by the sigmoidoscopist. Seventy-nine percent of the cases included here had only a single adenomatous polyp detected, and 15 percent had two polyps detected. Approximately 41 percent of the adenomas were less than 0.5 cm, 32 percent were 0.5–1 cm, and 27 percent were greater than 1 cm.

Five hundred nineteen cases and 556 controls completed a 126-item semiquantitative food frequency questionnaire (6) regarding diet in the year before sigmoidoscopy. The questionnaire allowed one of nine responses corresponding to servings of food eaten, ranging from "never or less than once per month" to "6 or more per day." We estimated the weekly intake of each food from these responses; when the questionnaire specified a range of possible intake values, we used the midpoint. If a subject failed to provide a response for a particular food, we set their intake of that item to zero. To calculate nutrient intake, we multiplied food intake—as reported in the questionnaire—by the nutrient levels in each food (7). The specific foods corresponding to items listed on the questionnaire were selected based on data from the 1988–1989 Nationwide Food Consumption Survey, Southwest Region (8). Nutrient levels for each of these foods was then obtained from the Nutrition Data System (9) and for carotenoid levels, from a nutrient database published recently by Mangels et al. (10). Participants also provided data on smoking, therapeutic drug use, physical activity, height, weight, family history of cancer, and other factors during an in-person interview. The interview was administered on average 5 months after sigmoidoscopy. The interviewer remained unaware of participants' disease status for 70 percent of cases and 87 percent of controls.

The present analysis was restricted to matched pairs. Unmatched controls occurred when, for example, the case to whom they were matched was found not to speak English ($n = 41$) or was found to have invasive large bowel cancer at follow-up colonoscopy ($n = 16$). Unmatched cases occurred when we were unable to interview a corresponding eligible control. Nineteen subjects with missing or "other" race values were assumed white. One control missing body mass index was given the mean value for controls. If family history of colorectal cancer were missing (12 percent of subjects), we assigned a category of no such history.

We defined 12 food groups containing vegetables, legumes, fruits, or grains based on common constituents and prior hypotheses (e.g., that cruciferous vegetables might be protective against polyps). The Appendix table 1 lists all foods contained in each grouping. Food group intake levels represent the summation of the intake across items in these groups. The "high carotenoid" groupings included those vegetables or fruits with more than 1,000 mcg/100 g of any of the following five carotenoids: alpha-carotene, beta-carotene, beta-cryptoxanthin, lutein, or lycopene (10). The "high vitamin C fruits" grouping included fruits with more than 30 mg of vitamin C per 100-g serving. We combined fruit juices into their own group because they differ substantially from whole fruits (e.g., they lack fiber, contain limited amounts of some labile compounds found in fruits, and often are not 100 percent juice). We also looked at individual foods, focusing primarily on vegetables that have been evaluated previously in the literature (i.e., broccoli, brussels sprouts, cabbage, carrots, cauliflower, and potatoes). In addition, we looked at garlic and tofu (or

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soybeans) because previous epidemiologic results for garlic (see below) and experimental evidence for soy products (11, 12) indicate that they might contain anticarcinogenic constituents.

We first calculated the mean vegetable, fruit, and grain intake levels for cases and controls; a paired t test was used to compare these means. We then used conditional logistic regression to estimate matched odds ratios (ORs) for food groups (across quintiles) and for specific foods, adjusting for the following covariates: race (four categories); body mass index (two categories); vigorous leisure time activity (three categories); smoking (three categories) (cutpoints for categorical variables are given in table 1); and saturated fat and energy (both continuous). The residual and energy-decomposition methods (7) gave results similar to those shown. We also present results further adjusted for dietary fiber, folate, beta-carotene, and vitamin C. Additional adjustment for intake of alcohol, vitamin E, vitamin A, retinol, iron, sources of fiber (i.e., vegetable, fruit, and grain fiber instead of total dietary fiber), vegetables (for fruit and grains), fruits (for vegetables and grains), grains (for vegetables and fruits), and total fat or red meat (instead of saturated fat) did not materially alter the results presented below. We estimated adjusted ORs for individual foods across three or four levels of servings (e.g., none, 0.5, and 1.0 servings per week)—depending on the distribution of intake—because the number of categories of intake we could usefully define was limited by the fact that most subjects reported eating a serving of a given food item either 0.5 times per week or not at all.

To address the multiple comparisons issue arising from looking at numerous individual foods, we also analyzed many of the data with a hierarchical model. This approach can give more plausible and stable estimates than conventional approaches by modeling similarities among parameters of interest in a second stage or "prior" model (13). Here, we used a second stage model to pull ordinary estimates of food effects toward each other when the corresponding foods had similar nutritional composition (with respect to fat, fiber, beta-carotene, and so forth). The hierarchical model gave results similar to those obtained from our conventional analysis—due, in part, to the reasonably large sample size; for the sake of familiarity, we

TABLE 1. Characteristics of study population (488 matched pairs aged 50–74 years who underwent screening sigmoidoscopy between 1991 and 1993 in southern California)

	Cases		Controls		p value†
	Mean	(SD*)	Mean	(SD)	
Mean age (years)	61.9	(6.7)	61.8	(6.8)	‡
Gender (% male)	66.6		66.6		‡
Race (%)					
White	55.3		53.9		0.77
African-American	15.8		17.8		
Hispanic	17.2		17.6		
Asian	11.7		10.7		
Body mass index (% ≥27 kg/m²)	49.0		41.7		0.02
Physical activity (% MET*) (hours/week)					
0	76.4		67.4		
1–3	10.9		12.9		
≥14	12.7		19.7		< 0.01
Smoking (%)					
Current	21.7		12.1		
Former	43.9		45.1		
Never	34.4		42.8		<0.01
Mean daily nutrient intakes					
Total energy (cal)	2,050	(841)	1,922	(804)	0.02
Saturated fat (g)	25.2	(13.1)	22.2	(12.3)	<0.01
Dietary fiber (g)	18.9	(9.6)	20.0	(9.7)	0.09
Folate (µg)	312	(146)	336	(157)	0.02
Beta-carotene (µg)	4,840	(4,290)	5,550	(4,650)	0.05
Vitamin C (mg)	137	(99.3)	154	(104)	0.01

* SD, standard deviation; MET, metabolic equivalent.
† From chi-square test comparing counts (i.e., for covariates given in percentages) or from paired t test comparing means.
‡ Matching variables.

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present the conventional results here. As a test for trend we compared linear, quadratic, and spline models (14): for each exposure, the linear model sufficiently assessed trend.

RESULTS

The subjects' average age was 62 years; two thirds were male, and slightly more than half were white (table 1). In comparison with controls, a notably higher percentage of cases were obese, exercised less, and smoked more often; cases also had higher mean calorie and saturated fat intake but lower intake of dietary fiber, folate, beta-carotene, and vitamin C.

On average, cases consumed fewer weekly servings of vegetables (26.4 vs. 29.9 for controls), fruits (12.3 vs. 13.8), and grains (22.4 vs. 23.3) (table 2). More specifically, cases consumed considerably fewer servings of vegetables and fruits high in carotenoids, cruciferous vegetables, leafy green vegetables, high vitamin C fruits, fruit juices, and whole grains. Cases and controls ate similar amounts of legumes, as well as processed grains.

In table 3, adjusted ORs for associations between polyps and vegetables and legumes are presented. Increased consumption of vegetables was clearly associated with decreased prevalence of colorectal adenomatous polyps: the OR comparing the highest with the lowest quintile was 0.47 (95 percent confidence interval (CI) 0.29–0.76). We observed similar inverse associations for vegetables high in carotenoids and for cruciferae, but a slightly weaker association for leafy green vegetables and no apparent association for legumes. Among individual vegetables, we observed inverse associations (comparing the highest intake levels with none) for broccoli (OR = 0.64, 95 percent CI 0.44–0.92), and cauliflower (OR = 0.75, 95 percer CI 0.52–1.09). Although the remaining vegetable (brussels sprouts, cabbage, carrots, and potatoes) ha ORs < 1.0, they appeared to be weakly or not associated with polyps. These ORs (first column of ORs i: table 3) were similar to the crude matched ORs (no shown). Further adjusting for dietary fiber, folate beta-carotene, and vitamin C weakened all of the vegetable associations. Nonetheless, the inverse associations remained for vegetables high in carotenoids cruciferous vegetables, and broccoli (table 3).

TABLE 2. Mean vegetable, fruit, and grain consumption (in servings per week) for cases and controls (488 matched pairs aged 50–74 years who underwent screening sigmoidoscopy between 1991 and 1993 in southern California)

Food (group)	Cases Mean	Cases (SD*)	Controls Mean	Controls (SD)	p value†
All vegetables	26.4	(17.1)	29.9	(18.7)	0.003
High carotenoid	15.2	(11.1)	17.6	(12.7)	0.002
Cruciferous	2.8	(2.8)	3.5	(4.3)	0.001
Leafy green	4.4	(3.7)	5.1	(4.4)	0.01
Legumes	3.6	(3.9)	3.7	(4.3)	0.73
All fruits	12.3	(10.7)	13.8	(11.0)	0.02
High carotenoid	3.2	(4.2)	3.6	(4.9)	0.11
High vitamin C	3.6	(5.0)	4.1	(4.3)	0.09
Fruit juices	5.0	(7.9)	5.5	(7.7)	0.04
Grains	22.4	(14.6)	23.3	(15.7)	0.40
Processed	16.3	(12.6)	16.0	(12.0)	0.66
Whole	6.1	(7.6)	7.3	(8.9)	0.02

* SD, standard deviation.
† From paired *t* test comparing means.

We also observed inverse associations for garlic (OR = 0.63, 95 percent CI 0.42–0.95) and tofu (or soybeans) (OR = 0.48, 95 percent CI 0.24–0.95) (table 4). These associations remained after further adjusting for dietary fiber, folate, beta-carotene, and vitamin C (table 4), as well as after adjusting for total fruit and vegetable intake (not shown).

In table 5, it can be seen that higher intake of fruit was somewhat associated with decreased prevalence of polyps, (OR = 0.65, 95 percent CI 0.40–1.05). For fruits high in carotenoids, there appeared to be an association when comparing the third and fourth quintiles with the first, but the OR comparing the fifth with the first quintile was only 0.75 (95 percent CI 0.48–1.18). Increased consumption of fruits high in vitamin C appeared inversely associated with polyps (OR = 0.59, 95 percent CI 0.36–0.95). Drinking fruit juice did not appear to be associated with polyps. These results were similar to the crude matched results (not shown). All of these associations were almost completely attenuated by further adjusting for dietary fiber, folate, beta-carotene, and vitamin C intake (table 5).

Eating more grains—or whole grains—was associated with decreased prevalence of polyps (table 6). The adjusted OR for total grains (again, comparing the highest with the lowest quintile) was 0.55 (95 percent CI 0.33–0.91). Similarly, the OR for whole grains was 0.65 (95 percent CI 0.41–1.02). These ORs were slightly stronger than the crude matched ORs (not shown). Additional adjustment for dietary fiber, folate, beta-carotene, and vitamin C did not materially alter the grain association (OR = 0.58, 95 percent CI 0.33–0.99) but weakened the whole grain association (OR = 0.78, 95 percent CI 0.48–1.27). Intake of processed (i.e., refined) grains was not associated with polyps.

In addition to looking at the individual foods specified a priori, we also explored the potential associations between the other individual foods (listed in the Appendix table) and polyps. This was done because grouping foods might cause one to miss potential associations for individual foods if the groups happen to be defined according to characteristics that are unrelated to risk. Of these foods, the following were inversely associated with polyps (after adjusting for race, body mass index, physical activity, smoking, energy, and saturated fat): yellow squash, eggplant (or zucchini or summer squash), romaine (or leaf) lettuce, bananas, apples (or pears), oranges, grapefruit, cold breakfast cereal, dark bread, and brown rice. After further adjusting for dietary fiber, folate, beta-carotene, and vitamin C, the associations remained, albeit slightly attenuated, for eggplant (or zucchini or summer squash), bananas, grapefruit, cold breakfast cereal, dark bread, and brown rice. Specific results for the individual foods are available on request.

Finally, stratifying by gender, polyp size (cutpoint = 1 cm), number of polyps (i.e., one polyp vs. more than one polyp), family history of colon cancer, or previous negative sigmoidoscopy (vs. no previous sigmoidoscopy) did not materially modify the results presented here, nor did removing 15 matched pairs wherein the case had carcinoma in situ at the time of colonoscopy.

DISCUSSION

Our findings support the hypothesis that high intake of vegetables, fruits, or grains decreases the risk of colorectal adenomatous polyps. Numerous previous investigations have associated increased consumption of these foods—or their constituents, such as fiber—with decreased risk of colorectal cancer (1, 15) and colorectal adenomas (4, 16, 17). Our results were not materially altered by mutually adjusting the food groups, (i.e., including vegetables, fruits, and grains in a single model) or by combining total fruit and vegetable intake, or total high carotenoid fruit and vegetable intake, into single exposures (not shown). Adjusting for intake of dietary fiber, folate, beta-carotene, and vitamin C almost completely removed the fruit association but only slightly attenuated the inverse associations for high carotenoid and cruciferous vegetables and grains. This suggests that the potential protective effects of vegetables and grains on polyps might not simply reflect dietary fiber or commonly measured antioxidants in these foods (assuming that these constituents were measured accurately). Instead, anticarcinogenic properties of constituents in vegetables or grains that are not usually measured in studies of diet (or constituent interactions) might be responsible for the inverse associations we observed. In fact, Macquart-Moulin et al. (18) found the protective effect of vegetable intake to be strongest for vegetables lowest in fiber, suggesting that some factors other than fiber were responsible for the inverse association. Moreover, recent trials looking at the effects of common antioxidant vitamin supplements on the recurrence of colon polyps remain equivocal (19–21).

The inverse association we observed for the high carotenoid vegetable group could reflect the high carotenoid content—for the five carotenoids defining this group—acting as a marker of some protective constituent(s) that have not yet been studied, such as the individual or joint effects of the other carotenoids contained in these foods. Similarly, the cruciferous vegetable and broccoli effects could also be due to some unmeasured, interacting, or unknown constituents. Other anticarcinogenic constituents in cruciferous vegetables include dithiolthiones, glucosinolates, indoles, and isothiocyanates (22). Broccoli also contains sulforaphane, which (experimentally) detoxifies carcinogenic compounds (23); and all green plant parts contain chlorophyll, which modifies genotoxic effects of known toxicants (24).

We observed an inverse association between increasing garlic consumption and polyps. Garlic contains diallyl sulfide and allyl methyl trisulfide, allium compounds that might be responsible for the apparent protective effect inasmuch as they can induce enzymatic systems involved with detoxifying carcinogens and can inhibit the bacterial formation of carcinogenic nitrosamines (22). Fructooligosaccharides make up another group of potentially protective allium constituents (25). Unfortunately, we were unable to look at associations between other allium vegetables (e.g., onions, chives) and polyps because our food frequency questionnaire did not measure these. Of seven previous studies that investigated allium vegetables and colon cancer (26–32), all but one (26) have reported inverse associations.

We found that higher consumption of tofu (or soybeans) was inversely associated with polyps. Although overall legume intake did not appear protective against polyps in this or previous studies (4), we looked at consumption of tofu (or soybeans) because they contain a number of potentially anticarcinogenic constituents, including isoflavones, saponins, genistein, and phytosterols (11, 12). We were able to look at tofu (or soybeans) as a single food item (i.e., separate from legumes) because almost 15 percent of our multiethnic study population reported consuming tofu (or soybeans) at least once a week.

The inverse association we observed between consumption of fruit and polyps agrees with most previous results (4). Because the fruit effects essentially disappeared when we adjusted for dietary fiber, folate, beta-carotene, and vitamin C, these constituents (or other highly correlated constituents) might explain the association with fruit.

TABLE 3. Adjusted matched odds ratios for colorectal polyps by quintiles of intake of vegetable and legume groups and by levels of intake of selected individual vegetables (488 matched pairs aged 50–74 years who underwent screening sigmoidoscopy between 1991 and 1993 in southern California)

Exposure*	OR_1†	95% CI†	OR_2†	95% CI
Food group				
All vegetables				
Q1 (9.0)	1.00		1.00	
Q2 (15.5)	0.85	0.55–1.31	0.94	0.60–1.48
Q3 (21.5)	0.91	0.59–1.39	1.04	0.67–1.62
Q4 (30.0)	0.71	0.46–1.11	0.81	0.50–1.33
Q5 (45.5)	0.47	0.29–0.76	0.90	0.49–1.68
	$p < 0.001$‡		$p = 0.27$	
High carotenoid vegetables				
Q1 (4.5)	1.00		1.00	
Q2 (8.0)	0.85	0.56–1.29	0.80	0.52–1.22
Q3 (11.5)	0.71	0.47–1.08	0.82	0.53–1.28
Q4 (17.0)	0.80	0.53–1.23	0.87	0.54–1.40
Q5 (28.0)	0.45	0.28–0.71	0.56	0.31–1.02
	$p = 0.001$		$p = 0.06$	
Cruciferous vegetables				
Q1 (0.5)	1.00		1.00	
Q2 (1.5)	0.86	0.54–1.36	0.93	0.58–1.48
Q3 (2.0)	0.87	0.60–1.28	0.98	0.66–1.44
Q4 (3.5)	0.69	0.45–1.07	0.82	0.52–1.27
Q5 (7.0)	0.51	0.33–0.80	0.67	0.41–1.09
	$p = 0.003$		$p = 0.07$	
Leafy green vegetables				
Q1 (1.0)	1.00		1.00	
Q2 (2.0)	1.10	0.73–1.63	1.17	0.78–1.75
Q3 (4.0)	0.87	0.55–1.37	0.94	0.59–1.50
Q4 (6.5)	0.77	0.51–1.16	0.91	0.59–1.41
Q5 (9.5)	0.65	0.42–1.02	0.88	0.53–1.44
	$p = 0.02$		$p = 0.49$	
Legumes				
Q1 (0.5)	1.00		1.00	
Q2 (1.5)	1.00	0.66–1.51	1.12	0.74–1.72
Q3 (2.0)	0.71	0.48–1.06	0.83	0.55–1.27
Q4 (4.0)	0.93	0.63–1.37	1.08	0.72–1.61
Q5 (8.5)	0.85	0.56–1.28	1.10	0.70–1.72
	$p = 0.17$		$p = 0.70$	

Table continues

The grain association we observed was not substantially reduced by adjusting for dietary fiber, folate, beta-carotene, and vitamin C (or other commonly measured antioxidants, including vitamin E). As discussed above for vegetables, this implies that some other constituents or constituent interactions in grains might explain the inverse associations. Possible anticarcinogenic constituents of grains include phytates and protease inhibitors. Furthermore, many grains contain high levels of resistant starch, which may reduce colonic cell proliferation by increasing bacterial fermentation (25). Thorough discussions of the potential anticarcinogenic constituents in vegetables, fruits, and grains are presented elsewhere (see, for example, (22, 33, 34).

Strengths of this study included screening all subjects for a first diagnosis of polyps, using a large sample size, and attaining a high response rate (>80 percent for both cases and controls). In addition, we were able to undertake a comprehensive assessment of potential confounders. Weaknesses of this study included only looking at adenomas in the left side of the colon, estimating diet with a food frequency questionnaire, and the potential for recall bias. Approximately 20–50 percent of the subjects with no family history of colorectal cancer could have had right-sided polyps not detected by the sigmoidoscope (35, 36). If food group effects do not differ by large bowel site, our results are generalizable to the entire colon but subject

TABLE 3. Continues

Exposure*	OR_1†	95% CI†	OR_2†	95% CI
Food				
Broccoli				
None	1.00		1.00	
0.5	0.73	0.50–1.08	0.77	0.52–1.14
≥1.0	0.64	0.44–0.92	0.75	0.51–1.11
	$p = 0.01$		$p = 0.10$	
Brussels sprouts				
None	1.00		1.00	
0.5	0.66	0.47–0.94	0.71	0.50–1.01
≥1.0	0.85	0.50–1.44	0.98	0.56–1.69
	$p = 0.22$		$p = 0.17$	
Cabbage				
None	1.00		1.00	
0.5	1.15	0.82–1.62	1.25	0.88–1.78
1.0	0.98	0.64–1.49	1.15	0.74–1.78
≥1.5	0.93	0.57–1.50	1.25	0.74–2.10
	$p = 0.29$		$p = 0.75$	
Carrots				
None	1.00		1.00	
0.5–1.0	1.00	0.70–1.43	1.10	0.76–1.59
1.5–3.0	0.84	0.57–1.24	1.01	0.67–1.54
≥3.5	0.80	0.53–1.20	1.14	0.69–1.87
	$p = 0.02$		$p = 0.88$	
Cauliflower				
None	1.00		1.00	
0.5	0.77	0.56–1.06	0.81	0.59–1.13
≥1.0	0.75	0.52–1.09	0.90	0.61–1.33
	$p = 0.04$		$p = 0.38$	
Potatoes				
None	1.00		1.00	
0.5	0.68	0.47–0.97	0.69	0.48–1.00
1.0–2.5	0.87	0.61–1.24	0.95	0.66–1.38
≥3.0	0.71	0.41–1.21	0.83	0.48–1.46
	$p = 0.35$		$p = 0.88$	

* See Appendix for listing of food groups. For food groups, quintile medians in servings per week given in parentheses. For foods, categories defined by servings per week.

† OR_1, odds ratio adjusted for race, body mass index, physical activity, smoking, calories, and saturated fat using conditional logistic regression; CI, confidence interval; OR_2, odds ratio adjusted for factors in OR_1 plus dietary fiber, folate, beta-carotene, and vitamin C.

‡ p value for trend.

to minimal bias toward the null inasmuch as some controls could have had right-sided polyps. Otherwise, if food effects do differ by colon site, our results remain unbiased although they pertain only to left-sided polyps. By looking at prevalent polyps, our results could reflect the effects of food on the progression from polyp to carcinoma, instead of on the transition from normal to neoplastic mucosa. However, stratifying our study subjects by previous negative sigmoidoscopy and by size of polyp did not alter our results.

In using a food frequency questionnaire, we could only approximate consumption (6, 37). The food frequency questionnaire responses likely overestimated average vegetable, fruit, and grain consumption—which are assessed with similar accuracy—due to the large number of items included in the questionnaire, or to the subjects' inclination to overreport foods perceived as being healthy (37). Nevertheless, this overestimation may not bias our results because it does not necessarily affect the relative ranking of subjects' intake and because none of the subjects received dietary recommendations. Moreover, the existence of polyps probably did not cause subjects to alter their food intake in the year before sigmoidoscopy inasmuch as most participants were asymptomatic (others were at most mildly symptomatic). In fact, stratifying our subjects by whether they reported a postsigmoidoscopy

TABLE 4. Adjusted matched odds ratios for colorectal polyps by levels of garlic and tofu (or soybeans) intake (488 matched pairs aged 50–74 years who underwent screening sigmoidoscopy between 1991 and 1993 in southern California)

Exposure*	OR_1†	95% CI†	OR_2†	95% CI
Garlic				
None	1.00		1.00	
0.5	0.94	0.66–1.35	0.92	0.64–1.34
1.0–2.5	0.94	0.60–1.49	0.98	0.61–1.56
≥3.0	0.63	0.42–0.95	0.66	0.43–1.01
	$p = 0.02$		$p = 0.01$	
Tofu or soybeans				
None	1.00		1.00	
0.5	0.85	0.50–1.45	0.89	0.49–1.45
≥1.0	0.48	0.24–0.95	0.55	0.27–1.11
	$p = 0.04$		$p = 0.17$	

* Categories of food defined by servings per week.

† OR_1, odds ratio adjusted for race, body mass index, physical activity, smoking, calories, and saturated fat using conditional logistic regression; CI, confidence interval; OR_2, odds ratio adjusted for factors in OR_1 plus dietary fiber, folate, beta-carotene, and vitamin C.

TABLE 5. Adjusted matched odds ratios for colorectal polyps by quintiles of intake of fruit groups (488 matched pairs aged 50–74 years who underwent screening sigmoidoscopy between 1991 and 1993 in southern California)

Exposure*	OR_1†	95% CI†	OR_2†	95% CI
All fruits				
Q1 (2.5)	1.00		1.00	
Q2 (6.5)	0.70	0.46–1.08	0.77	0.49–1.19
Q3 (11.0)	0.68	0.45–1.05	0.79	0.50–1.24
Q4 (16.0)	0.61	0.39–0.97	0.74	0.45–1.22
Q5 (25.0)	0.65	0.40–1.05	0.92	0.52–1.63
	$p = 0.09$		$p = 0.99$	
High carotenoid fruits				
Q1 (0.0)	1.00		1.00	
Q2 (1.0)	0.80	0.54–1.19	0.83	0.56–1.24
Q3 (2.0)	0.55	0.36–0.84	0.60	0.38–0.92
Q4 (3.5)	0.59	0.37–0.93	0.66	0.41–1.05
Q5 (8.0)	0.75	0.48–1.18	0.93	0.58–1.51
	$p = 0.19$		$p = 0.83$	
High vitamin C fruits				
Q1 (0.0)	1.00		1.00	
Q2 (1.0)	0.92	0.60–1.41	0.97	0.63–1.49
Q3 (2.5)	0.73	0.48–1.10	0.78	0.51–1.20
Q4 (4.5)	0.62	0.39–0.99	0.76	0.47–1.24
Q5 (8.5)	0.59	0.36–0.95	0.80	0.47–1.35
	$p = 0.17$		$p = 0.61$	
Fruit juices				
Q1 (0.0)	1.00		1.00	
Q2 (1.0)	1.36	0.87–2.12	1.35	0.86–2.13
Q3 (3.0)	1.18	0.79–1.75	1.28	0.85–1.92
Q4 (6.5)	0.88	0.56–1.37	0.93	0.59–1.48
Q5 (11.0)	0.90	0.57–1.41	1.21	0.74–1.99
	$p = 0.45$		$p = 0.21$	

* See Appendix for listing of food groups. Quintile medians in servings per week given in parentheses.

† OR_1, odds ratio adjusted for race, body mass index, physical activity, smoking, calories, and saturated fat using conditional logistic regression; CI, confidence interval; OR_2, odds ratio adjusted for factors in OR_1 plus dietary fiber, folate, beta-carotene, and vitamin C.

TABLE 6. Adjusted matched odds ratios for colorectal polyps by quintiles of intake of grains (488 matched pairs aged 50–74 years who underwent screening sigmoidoscopy between 1991 and 1993 in southern California)

Exposure*	OR_1†	95% CI†	OR_2†	95% CI
Grains				
Q1 (8.0)	1.00		1.00	
Q2 (13.5)	0.78	0.51–1.20	0.80	0.51–1.23
Q3 (19.5)	0.84	0.55–1.30	0.87	0.55–1.37
Q4 (27.0)	0.78	0.50–1.21	0.79	0.49–1.25
Q5 (42.5)	0.55	0.33–0.91	0.58	0.33–0.99
	$p = 0.05$		$p = 0.07$	
Processed grains				
Q1 (4.5)	1.00		1.00	
Q2 (9.0)	0.85	0.58–1.26	0.90	0.60–1.34
Q3 (13.0)	0.97	0.63–1.49	1.05	0.66–1.65
Q4 (18.5)	0.86	0.56–1.34	0.90	0.57–1.42
Q5 (30.5)	0.88	0.55–1.41	0.87	0.53–1.43
	$p = 0.60$		$p = 0.45$	
Whole grains				
Q1 (0.0)	1.00		1.00	
Q2 (1.0)	0.91	0.61–1.36	1.01	0.67–1.51
Q3 (3.5)	0.74	0.47–1.19	0.79	0.49–1.28
Q4 (7.0)	0.76	0.49–1.18	0.89	0.56–1.40
Q5 (18.0)	0.65	0.41–1.02	0.78	0.48–1.27
	$p = 0.01$		$p = 0.06$	

* See Appendix for listing of food groups. Quintile medians in servings per week given in parentheses.
† OR_1, odds ratio adjusted for race, body mass index, physical activity, smoking, calories, and saturated fat using conditional logistic regression; CI, confidence interval; OR_2, odds ratio adjusted for factors in OR_1 plus dietary fiber, folate, beta-carotene, and vitamin C.

change in diet gave results similar to those presented here.

In conclusion, the strongest association we observed was for vegetables—including those high in carotenoids, cruciferae, and broccoli—as well as for garlic and tofu (or soybeans), and these associations were found even after adjusting for dietary fiber, folate, beta-carotene, vitamin C, and other commonly measured antioxidants. This finding conforms with previous published results showing that, across studies, the most consistent decrease in colorectal cancer risk is from vegetables, not fiber. Moreover, our observation of potentially protective fruit and grain effects also substantiates earlier investigations (1, 4, 17). Adjusting for fiber and commonly measured antioxidants dissolved the fruit effect but only marginally reduced the grain association. Clearly, additional research into the effects of potentially anticarcinogenic constituents of vegetables (as well as tofu, garlic, fruits, and grains) on colorectal polyps and cancer is warranted.

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APPENDIX TABLE 1. Definitions of vegetable, fruit, and grain groups

	All vegetables	
All "high carotenoid vegetables" (below)	Beets	Corn
Alfalfa sprouts	Cabbage or coleslaw	Iceberg or head lettuce
Beans or lentils	Cauliflower	Potatoes
	Celery	String beans
	High carotenoid vegetables	
Broccoli	Mixed vegetables	Tomatoes
Brussels sprouts	Peas or lima beans	Tomato juice
Carrots (raw and cooked)	Red chili sauce	Tomato sauce
Eggplant, zucchini, or other summer squash	Romaine or leaf lettuce	Yams or sweet potatoes
Kale, mustard, or chard greens	Spinach (raw and cooked)	Yellow (winter) squash
	Cruciferous vegetables	
Broccoli	Cabbage or coleslaw	Kale, mustard, or chard greens
Brussels sprouts	Cauliflower	
	Leafy green vegetables	
Iceberg or head lettuce	Romaine or leaf lettuce	Spinach (raw and cooked)
Kale, mustard, or chard greens		
	Legumes	
Beans or lentils	Peas or lima beans	Tofu or soybeans
Peanut butter		
	All fruits	
All "high vitamin C fruits" (below)	Blueberries	Raisins or grapes
Apples or pears	Peaches, apricots, or plums	Watermelon
Bananas	Prunes	
	*High carotenoid fruits**	
Cantaloupe	Peaches, apricots, or plums	Watermelon
Grapefruit (i.e., red)		
	High vitamin C fruits†	
Cantaloupe	Oranges	Strawberries
Grapefruit (i.e., red)		
	Fruit juices	
Apple juice or cider	Orange juice	Other fruit juice
Grapefruit juice		
	Grains	
	All "processed grains" and "whole grains" (below)	
	Processed grains	
Crackers, Triskets, Wheat Thins	Muffins or biscuits	Cooked oatmeal
Cold breakfast cereal	Pancakes or waffles	White bread
Other cooked breakfast cereal	Pasta	White rice
English muffins, bagels, or rolls		
	Whole grains	
Bran, added to food	Other grains, e.g., bulgar, kasha, couscous	Dark bread
Brown rice		Wheat germ

* Foods containing > 1,000 μg of carotenoids (alpha-carotene, beta-carotene, beta-cryptoxanthin, lutein, or lycopene) per 100-g serving.
† Fruits containing > 30 mg of vitamin C per 100-g serving.