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Abstract

Background
The contribution of specific nutrients to obesity has not been definitively established. The objective of this study was to determine if an association exists between obesity and the relative percentages of fats, carbohydrates, protein and fibre in the diets of Canadians.

Data and methods
The data are from the 2004 Canadian Community Health Survey—Nutrition. The analysis pertains to 6,454 respondents aged 18 or older who provided valid 24-hour dietary recall information and measured height and weight, and whose reported energy intake was considered plausible based on their predicted energy expenditure. Logistic regression models with obesity status as the main outcome were conducted, controlling for potential confounders. All analyses were based on weighted estimates.

Results
When the effect of the control variables was taken into account, total kilocalories consumed increased the odds of obesity in men, and fibre intake decreased the odds. Among women, only total kilocalories consumed was significantly associated with increased odds of obesity.

Interpretation
Higher consumption of kilocalories increased the odds of obesity, but the relative amounts of fats, carbohydrates and protein were generally not significant. The sole exception was an association between higher fibre intake and lower rates of obesity among men.

Keywords
carbohydrate, energy intake, fat, fibre, protein, 24-hour recall

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The prevalence of obesity has been rising in Canada in recent decades.[1] By 2004, 23.1% of adults were obese, nearly ten percentage points higher than in 1978 (13.8%).[2] Dietary composition—the relative proportions of calories coming from fats, carbohydrates and protein, and intake of fibre—has been suspected of playing a role in obesity.[3,4] However, few studies have examined the association between excess weight and the consumption of these nutrients, and the results are inconsistent.[5-12] The unexpected and sometimes contradictory findings may be due to differences in sample size, time frames, and variations in how excess weight is measured. In addition, some of the studies could not account for key factors, including total energy intake[5] and/or physical activity levels.[9] Others were unable to adjust for under-reporting of calories consumed[5,7-11]—a shortcoming of many nutrition studies.[13-16]

The objective of this study was to determine if an association exists between the relative percentages of fats, carbohydrates, protein and fibre in a diet and excess weight among Canadian adults. Unlike most earlier studies, the analysis is based on recent nationally representative Canadian data. This analysis overcomes many of the shortcomings of past research by controlling for total energy intake, physical activity levels, and under-reporting. It is the first study to investigate the contribution of dietary composition to excess weight among Canadians.

Data and methods

The data are from the 2004 Canadian Community Health Survey—Nutrition, cycle 2.2, which was designed to collect information on the nutritional status of Canadians. The survey excludes members of the Canadian Forces; residents of the three territories, Indian reserves, institutions and some remote areas; and military and civilian residents of the Canadian Forces bases. Detailed descriptions of the survey design, sample and interview procedures are available in a published report.[17]

A total of 35,107 respondents completed an initial 24-hour dietary recall, of all foods and beverages consumed from midnight to midnight during the previous 24 hours. To maximize recall, the five-step Automated Multiple Pass Method[18,19] was used:

- a quick list of the foods consumed;
- questions about commonly forgotten food categories;
- questions about the time and type of meals;
- questions to collect more detailed information about the foods and the quantities consumed; and
- a final review.

A subsample of 10,786 respondents completed a second 24-hour recall three to ten days later. The response rate to the first recall was 76.5%, and to the second, 72.8%. This study uses data from the first recall only. Even though the Automated Multiple Pass Method was developed to maximize recall, a validation study in the United States identified under-reporting of energy intake by 11%.[20]

An advantage of the Canadian Community Health Survey is that, for about 60% of respondents, measured height and weight information is available. Actual measurements are more accurate for determining obesity than are self-reported height and weight, which tend to underestimate prevalence.[21-23] To minimize non-response bias, a special (adjusted) survey weight was created for respondents with measured height and weight, based on subject classes with similar socio-demographic characteristics. The adjusted weights were used to produce all estimates in this study.

Previous analysis of Canadian Community Health Survey data identified a substantial percentage of respondents who under- or over-reported the number of kilocalories they consumed,[13] thereby masking the relationship between energy intake and obesity. One technique to overcome under- and over-reporting is to limit the study population to respondents with plausible reported energy intakes.[24,25] Respondents were identified as plausible reporters based on a comparison of their total predicted energy expenditure and their reported energy intake, according to the methodology of Garriguet.[26] An energy expenditure value was predicted for each respondent, based on age, weight, sex, height, physical activity and body mass index (BMI) category. The ratio of reported energy intake to predicted energy expenditure was then calculated. A range in the form of [exp(-SD); exp(SD)] was assigned to this ratio, where SD represents a standard deviation. Taking into account intra-individual variation of energy intake, the error in predicted requirements and day-to-day variation, and the measurement error for total energy expenditure, SD was estimated at 35%, yielding a range of 0.70 to 1.42.[26] Based on the assumption of a weight-stable population, respondents whose ratio fell within this range were considered "plausible" respondents, that is, their reported energy intake was 70% to 142% of their predicted energy expenditure. More information on the identification of plausible respondents is available in a published report.[26]

Only respondents aged 18 or older whose body mass index was based on measured height and weight were included in this study (n=12,092). Pregnant (n=100) and breast-feeding (n=69) women, respondents with null (n=4) or invalid (n=18) dietary intakes, and respondents with missing information on leisure-time physical activity (n=2) were excluded. Respondents classified as underweight (BMI less than 18.5) (n=249) were also excluded, because the equations used to predict energy requirements apply only to people whose BMI is at least 18.5.[4] Finally, under- (n=4,625) and over-reporters (n=1,013) were excluded. The sample on which this analysis is based consisted of 6,454 respondents (n=2,804 men and n=3,650 women) with plausible reported energy intake.

Definitions

Obesity was defined based on Health Canada's body weight classification system,[27] adapted from the World Health Organization.[28] Respondents with a BMI equal to or more than 18.5 but less than 25 were considered normal weight; those whose BMI was equal to or more than 25 but less than 30 were considered overweight; and those whose BMI was 30 or more were considered obese. BMI was calculated based on measured height and weight, using the formula: weight (kg) / height $(m)^2$. Obese subjects were compared with normal and overweight respondents combined.

The Canadian Nutrient File is a computerized database developed by Health Canada that contains average values for the nutrients in foods available in Canada.[29] The Canadian Nutrient File (2001b Supplement)[30] was used to determine the energy and nutrient composition of the foods and beverages reported during the recalls.

Total energy intake is examined in 100s of kilocalories. Total fats, carbohydrates, and protein are presented as a percentage of total energy intake. Dietary fibre was examined in grams per 100 kilocalories. The breakdown of total fat (saturated, monounsaturated, and polyunsaturated) was also examined in terms of percentage of total energy intake.

Age was modeled according to the following groups: 18 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, and 75 or older. These ranges were selected because previous analyses found that rates of obesity varied across these age groups,[1,2] and the sample size permitted such a breakdown.

Household income was based on the number of people in the household and

total household income from all sources in the 12 months before the interview. Household income groups were derived by calculating the ratio between each respondent's total household income in the previous 12 months and Statistics Canada's low-income cut-off specific to the number of people in the household, the size of the community and the survey year.[31] These adjusted income ratios are presented in quintiles. A missing category was included to reflect respondents for whom income information was not available.

Education was classified as less than secondary graduation, secondary graduation, some postsecondary, and postsecondary graduation.

An *ethnic origin* variable was included in the model, which, because of small sample sizes, was collapsed into three categories: White, Aboriginal, and other. Current information about obesity rates among Aboriginal people[32] suggests that this should be a separate category.

Smoking status was classified as current smoker, former smoker, and never smoked.

Marital status was classified as married/common-law, widowed, separated/divorced, and never married.

Leisure-time physical activity refers to the three months before the interview. The duration and frequency of each reported activity (for example, walking, gardening, swimming and running) were assessed. Metabolic energy costs (METs)—the amount of energy required to participate in the activity per kilogram of body weight per hour of activity—were assigned to each activity and used to calculate each respondent's average daily energy expenditure (EE) by multiplying frequency by duration and MET value divided by 365 days. Based on their average daily energy expenditure, each respondent was classified as inactive (EE less than 1.5), moderately active (EE greater than or equal to 1.5, but less than 3.0), or active (EE 3.0 or more). (To identify plausible reporters, physical activity was broken down into four categories—sedentary, low-active, active, very active—to be consistent with the methodology of Garriguet.)[26]

Analysis

Descriptive statistics were used to examine the characteristics of Canadians who were obese. Chi-squares and t-tests were used to determine significant differences among the groups.

Logistic regression was used to determine the relationship between obesity and dietary composition and other covariates. Logistic regression models were conducted separately by sex. Established risk factors and/or characteristics known to be associated with obesity were included as control variables: age, marital status, education, race, income, smoking, leisure-time physical activity, and total energy intake.[2,6,8,32,33] Models were run separately for each nutrient, unadjusted and then adjusted for the control variables. A final model was run with all nutrients and control variables simultaneously.

To account for the complex sampling design of the Canadian Community Health Survey, the bootstrap method was used to estimate standard errors, coefficients of variation, and confidence intervals.[34-36] Significance levels were set at $p < 0.05$. Analyses were conducted using SAS version 9.1 (Statistical Analysis System, SAS Institute Inc., Cary, NC, USA). The bootstrapping technique was used with SUDAAN (version 10)[37] software.

Results

The sample

The sample of 6,454 respondents to the 2004 Canadian Community Health Survey, on which this analysis is based, was weighted to represent a population of 12.9 million aged 18 or older (Table 1). They were almost evenly divided between men and women. Nearly two-thirds (65%) were married. More than half (54%) were postsecondary graduates. One-quarter were smokers, and 29% were former smokers; 46% had never smoked. Almost 60% were

Table 1
Prevalence of selected characteristics of sample, household population aged 18 or older with plausible energy intake, Canada excluding territories, 2004

Characteristic	Sample size	Estimated population	
		Number '000	%
Total	6,454	12,918	100.0
Body mass index			
Obese	1,565	2,823	21.9
Not obese	4,889	10,094	78.1
Sex			
Men	2,804	6,485	50.2
Woman	3,650	6,432	49.8
Age group			
18 to 24	707	1,569	12.1
25 to 34	852	2,062	16.0
35 to 44	820	2,755	21.3
45 to 54	1,076	2,483	19.2
55 to 64	1,054	1,950	15.1
65 to 74	927	1,153	8.9
75 or older	1,018	946	7.3
Marital status			
Married/Common-law	3,300	8,328	64.5
Widowed	920	693	5.4
Separated/Divorced	698	1,059	8.2
Never married	1,534	2,834	21.9
Education			
Less than secondary graduation	1,670	2,406	18.8
Secondary graduation	1,120	2,335	18.3
Some postsecondary	592	1,169	9.1
Postsecondary graduation	3,033	6,874	53.8
Household income			
First quintile (lowest)	1,263	2,124	16.4
Second quintile	1,249	2,328	18.0
Third quintile	1,151	2,506	19.4
Fourth quintile	1,143	2,493	19.3
Fifth quintile (highest)	1,131	2,464	19.1
Missing	517	1,002	7.8
Ethnic origin			
White	5,837	10,736	83.1
Aborginal (off-reserve)	225	190	1.5
Other	392	1,992	15.4
Smoking status			
Current smoker	1,565	3,238	25.1
Former smoker	2,003	3,697	28.6
Never smoked	2,884	5,973	46.3
Leisure-time physical activity			
Inactive	3,751	7,652	59.2
Moderately active	1,576	3,093	23.9
Active	1,127	2,173	16.8

Source: 2004 Canadian Community Health Survey—Nutrition.

inactive in their leisure time, and 22% were obese.

Prevalence of obesity

Men and women were equally likely to be obese (22%) (Table 2). For both sexes, the prevalence of obesity tended to rise with age, peaking in the 45 to 64 age range. However, among men but not women, prevalence dropped sharply at age 75 or older.

Marital status was related to obesity among women, but not among men. Compared with those who had never been married, women who were married, widowed, or separated/divorced were more likely to be obese.

As well, among women, but not men, household income was associated with obesity. Women in the lower three income quintiles were more likely than those in the highest quintile to be obese.

Education was related to obesity, especially among men. Men with secondary graduation or less were more likely than postsecondary graduates to be obese. Among women, the difference was significant only for those with less than secondary graduation.

For both sexes, those who were moderately active or active in their leisure time were less likely than those who were inactive to be obese.

Nutrition

Not surprisingly, obese men consumed significantly more calories (2,820 versus 2,600 calories) than did non-obese men (Table 3). As well, the diets of obese men contained higher percentages of total fat, saturated fat, and monounsaturated fat than was the case for non-obese men. On the other hand, obese men consumed relatively less carbohydrates and fibre than did their non-obese counterparts.

Among women, too, those who were obese consumed significantly more calories than did the non-obese (2,160 versus 1,970). And as was true for men, women who were obese consumed significantly less fibre than did non-obese women.

Each nutrient was modeled separately to examine its individual effect on obesity, in unadjusted models (no control variables), and then adjusted for other characteristics, including total energy intake (Table 4). The unadjusted logistic regression models showed increased odds of obesity among men with higher consumption of energy and total fat; consumption of fibre decreased men's odds of obesity, and carbohydrates were also significant. When adjusted for covariates, total energy intake and fibre remained significantly associated with obesity among men: higher energy intake increased their odds of

Table 2
Weighted prevalence of obesity, by sex and selected characteristics, household population aged 18 or older with plausible energy intake, Canada excluding territories, 2004

	Men				Women			
	Estimated number		95% confidence interval		Estimated number		95% confidence interval	
Characteristic	'000	%	from	to	'000	%	from	to
Total	**6,485**	**21.7**	**18.9**	**24.9**	**6,432**	**22.0**	**19.2**	**25.0**
Age group								
18 to 24†	860	11.2E	6.1	19.7	709	11.2E	6.9	17.8
25 to 34	1,169	22.2E	14.3	32.8	893	19.8E	13.7	27.7
35 to 44	1,347	18.9E	13.4	26.1	1,408	21.0*	15.1	28.4
45 to 54	1,182	28.5*	21.9	36.3	1,301	25.6*	18.3	34.6
55 to 64	966	29.6*	22.6	37.6	984	27.7*	21.1	35.3
65 to 74	573	20.7*	15.6	27.1	580	23.3*	17.9	29.7
75 or older	389	14.9E	8.8	24.1	556	21.8*	16.6	28.0
Marital status								
Married/Common-law	4,293	22.5	19.1	26.3	4,036	23.0*	19.3	27.2
Widowed	108	13.5‡E	7.7	22.5	585	26.7*	21.0	33.2
Separated/Divorced	434	26.3E	17.3	37.9	626	25.0*E	17.6	34.2
Never married†	1,649	19.2E	13.4	26.8	1,185	14.5E	9.5	21.5
Education								
Less than secondary graduation	1,153	28.3*	21.5	36.2	1,254	30.3*	23.4	38.3
Secondary graduation	1,058	36.5*‡	27.1	47.0	1,277	21.5	15.7	28.8
Some postsecondary	658	14.3E	8.9	22.2	511	23.8E	16.2	33.7
Postsecondary graduation†	3,587	16.8	13.8	20.3	3,287	18.6	15.3	22.5
Household income								
First quintile (lowest)	945	16.2E	9.3	26.8	1,179	25.6*	19.1	33.5
Second quintile	1,149	19.6E	13.8	27.1	1,179	24.2*	18.5	30.9
Third quintile	1,316	27.6	20.6	35.8	1,190	25.9*	19.2	33.9
Fourth quintile	1,411	25.3	19.7	31.8	1,082	23.2	17.0	30.9
Fifth quintile (highest)†	1,285	21.6	17.1	27.0	1,180	14.0E	8.6	22.0
Missing	380	9.1*E	4.8	16.6	623	16.2E	9.9	25.5
Ethnic origin								
White†	5,330	24.7	21.4	28.3	5,406	23.2	20.2	26.4
Aborginal (off-reserve)	83	29.5E	14.9	50.1	107	37.3E	23.7	53.3
Other	F	F	F	F	920	12.9*E	7.1	22.3
Smoking status								
Current smoker	1,775	19.8	14.8	26.0	1,463	23.3	17.4	30.5
Former smoker	2,211	27.8*	22.2	34.3	1,486	24.1	18.8	30.4
Never smoked†	2,500	17.7	14.0	22.2	3,474	20.6	17.1	24.5
Leisure-time physical activity								
Inactive†	3,587	25.4	21.1	30.3	4,065	26.0	22.2	30.3
Moderately active	1,665	16.5*	12.4	21.6	1,428	19.2*	14.9	24.3
Active	1,233	18.1*‡	13.0	24.6	939	8.7*E	5.5	13.5

* significantly different from estimate for reference group (p<0.05)
‡ significantly different from estimate for women (p<0.05)
† reference group
E use with caution (coefficient of variation 16.6% to 33.3%)
F too unreliable to be published (coefficient of variation greater than 33.3%)
Note: Plausible respondents are those whose reported energy intake was 70% to 142% of their predicted energy expenditure.
Source: 2004 Canadian Community Health Survey—Nutrition.

Table 3
Daily intakes of selected nutrients, by sex and obesity status, household population aged 18 or older with plausible energy intake, Canada excluding territories, 2004

	Men						Women					
	Obese			Not obese			Obese			Not obese		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
Nutrient	Average	from	to	Average	from	to	Average	from	to	Average	from	to
Energy intake (average in 100s of kilocalories)	28.2*	27.3	29.1	26.0	25.5	26.4	21.6*	20.9	22.3	19.7	19.3	20.0
Carbohydrates (% of energy)	45.8*	44.1	47.5	48.1	47.2	48.9	48.9	47.2	50.7	49.8	48.9	50.7
Protein (% of energy)	16.0	15.3	16.7	15.8	15.4	16.2	15.8	14.5	17.1	15.6	15.1	16.1
Total fat (% of energy)	34.3*	32.9	35.8	32.1	31.3	32.9	33.3	32.4	34.3	32.3	31.6	33.0
Saturated fat (% of energy)	11.5*	10.6	12.4	10.2	9.8	10.6	10.7	10.0	11.3	10.6	10.2	10.9
Monounsaturated fat (% of energy)	14.0*	13.4	14.7	13.0	12.6	13.4	13.4	13.0	13.9	12.9	12.6	13.2
Polyunsaturated fat (% of energy)	5.7	5.2	6.1	5.8	5.5	6.0	6.1	5.7	6.4	5.8	5.6	6.0
Fibre (average grams per 100 kilocalories)	0.7*	0.7	0.8	0.8	0.8	0.8	0.8*	0.8	0.9	0.9	0.9	0.9

* significantly different from estimate for non-obese ($p<0.05$)
Note: Plausible respondents are those whose reported energy intake was 70% to 142% of their predicted energy expenditure.
Source: 2004 Canadian Community Health Survey—Nutrition.

Table 4
Unadjusted and adjusted odds ratios relating obesity to selected nutrients, by sex, household population aged 18 or older with plausible energy intake, Canada excluding territories, 2004

	Men						Women					
	Unadjusted odds ratio	95% confidence interval		Adjusted odds ratio	95% confidence interval		Unadjusted odds ratio	95% confidence interval		Adjusted odds ratio	95% confidence interval	
Nutrient		from	to		from	to		from	to		from	to
Energy intake (in 100s of kilocalories)	1.06*	1.03	1.09	1.08*	1.05	1.11	1.09*	1.06	1.13	1.15*	1.11	1.19
Carbohydrates (% of energy)	0.98*	0.96	1.00	0.99	0.98	1.01	0.99	0.98	1.01	1.00	0.99	1.02
Protein (% of energy)	1.01	0.98	1.03	1.02	0.99	1.05	1.01	0.96	1.05	1.01	0.98	1.05
Total fat (% of energy)	1.03*	1.01	1.05	1.01	0.99	1.03	1.01	1.00	1.03	1.00	0.98	1.01
Fibre (grams per 100 kilocalories)	0.50*	0.31	0.79	0.58*	0.34	0.98	0.68	0.45	1.03	0.76	0.51	1.12

* significantly different from 1.00 ($p<0.05$)
Note: Plausible respondents are those whose reported energy intake was 70% to 142% of their predicted energy expenditure. Each nutrient was modeled separately. Adjusted models controlled for age, marital status, ethnic origin, education, income, smoking, leisure-time physical activity, and total energy intake.
Source: 2004 Canadian Community Health Survey—Nutrition.

obesity, whereas fibre decreased their odds. Among women, high total calorie intake increased the odds of obesity in univariate analysis and in the presence of controls, but no other dietary factor was significantly associated with obesity.

In the fully adjusted models, total energy intake and fibre remained significantly associated with obesity among men; no other nutrient was significant (Table 5). For women, total energy intake was the only dietary factor significantly related to obesity.

Discussion

The analysis of data from the 2004 Canadian Community Health Survey—Nutrition found that higher total energy intake significantly increased the odds of obesity for men and women, but the composition of their diets—the relative percentages of carbohydrates, protein, fats, and fibre—was generally not a factor. The sole exception was the association between higher fibre intake and lower rates of obesity among men. It seems that for obesity, quantity (total energy intake) is more important than quality (the balance of nutrients consumed).

Fat is one of the most studied nutrients in the obesity literature, and possibly, the most controversial. Because of the higher calorie count of fats (9 kilocalories per gram versus 4 kilocalories per gram for both carbohydrates and protein), it is reasonable to assume that higher fat intake contributes to higher energy intake, and perhaps, excess consumption. In fact, those who consume a low-fat diet often unintentionally reduce their total energy intake.[38] However, consistent with earlier research,[5-7] this analysis found no association between total fat intake and obesity among men: obese men consumed more fat overall,

Table 5
Adjusted odds ratios relating obesity to selected characteristics, by sex, household population aged 18 or older with plausible energy intake, Canada excluding territories, 2004

	Men			Women		
	Adjusted odds ratio	95% confidence interval		Adjusted odds ratio	95% confidence interval	
Characteristics		from	to		from	to
Nutrient						
Energy intake (in 100s of kilocalories)	1.08*	1.04	1.11	1.15*	1.11	1.20
Carbohydrates (% of energy)	1.01	0.99	1.04	1.03	0.99	1.07
Protein (% of energy)	1.02	0.99	1.06	1.04	0.99	1.09
Total fat (% of energy)	1.01	0.99	1.04	1.02	0.98	1.05
Fibre (grams per 100 kilocalories)	0.58*	0.34	0.99	0.69	0.45	1.05
Age group						
18 to 24†	1.00	...	...	1.00	...	...
25 to 34	2.75	0.91	8.30	2.27	0.95	5.40
35 to 44	2.84	0.89	9.03	2.62*	1.10	6.26
45 to 54	4.87*	1.58	15.07	4.11*	1.58	10.71
55 to 64	5.42*	1.75	16.79	4.22*	1.65	10.78
65 to 74	3.33*	1.02	10.83	3.27*	1.38	7.74
75 or older	2.51	0.72	8.70	2.71*	1.08	6.80
Marital status						
Married/Common-law	0.71	0.37	1.36	1.37	0.71	2.63
Widowed	0.39	0.13	1.13	1.51	0.68	3.34
Separated/Divorced	0.84	0.36	1.95	1.47	0.64	3.38
Never married†	1.00	...	...	1.00	...	...
Education						
Less than secondary graduation	2.41*	1.53	3.80	2.11*	1.21	3.69
Secondary graduation	3.02*	1.81	5.04	1.05	0.68	1.62
Some postsecondary	1.15	0.55	2.38	1.79	0.99	3.22
Postsecondary graduation†	1.00	...	...	1.00	...	...
Household income						
First quintile (lowest)	0.86	0.44	1.69	2.03	0.94	4.36
Second quintile	1.04	0.60	1.83	1.85	0.89	3.87
Third quintile	1.21	0.73	1.99	2.21*	1.12	4.37
Fourth quintile	1.14	0.73	1.77	1.48	0.74	2.96
Fifth quintile (highest)†	1.00	...	...	1.00	...	...
Missing	0.40*	0.18	0.85	1.31	0.50	3.47
Ethnic origin						
White†	1.00	...	...	1.00	...	...
Aboriginal (off-reserve)	1.36	0.49	3.79	1.90	0.79	4.56
Other	0.28*	0.12	0.66	0.45*	0.21	0.97
Smoking status						
Current smoker	0.60*	0.36	1.00	0.78	0.45	1.34
Former smoker	1.30	0.84	2.00	0.95	0.65	1.39
Never smoked†	1.00	...	...	1.00	...	...
Leisure-time physical activity						
Inactive†	1.00	...	...	1.00	...	...
Moderately active	0.67	0.43	1.05	0.68	0.46	1.01
Active	0.61	0.36	1.02	0.27*	0.15	0.48

* significantly different from estimate for reference category or from 1.00 for continuous variables ($p<0.05$)
† reference category
... not applicable
Note: Plausible respondents are those whose reported energy intake was 70% to 142% of their predicted energy expenditure.
Source: 2004 Canadian Community Health Survey—Nutrition.

but when modeled in the presence of covariates, the relationship disappeared.

In this study, the relative percentages of total fat in the diets of obese and non-obese women did not differ significantly, so not surprisingly, no relationship emerged between fat intake and obesity. This is counter to the results of two earlier studies that found an association between women's fat intake and percent body fat[8] and BMI.[9] However, neither study accounted for under-reporting of energy intake, or more importantly, under-reporting of fat intake.[39,40]

Some studies have examined specific types of fats, because it has been suggested that saturated, monounsaturated and polyunsaturated fats might have different effects on adiposity.[41] As a supplementary analysis, the three types of fat were entered into the model instead of total fat. Monounsaturated fats increased the odds of obesity, and polyunsaturated fats decreased the odds of obesity among men, but not among women (Appendix Table A). No relationship with saturated fats emerged for either sex. These results are inconsistent with recent literature. A 2003 study of elderly people found a positive relationship between saturated fat intake and BMI among women (mono- and polyunsaturated fats were not examined).[9] A 2002 study of post-menopausal women showed monounsaturated fats to be positively related to weight; no relationship was found for polyunsaturated or saturated fats.[10] A 2008 ecological study found saturated fat and polyunsaturated fat intake to be positively associated with obesity prevalence, and monounsaturated fat intake to be negatively related,[12] which directly contradicts the present analysis. Both monounsaturated and polyunsaturated fats are considered "healthy" fats (they tend to lower blood cholesterol levels[42,43]), so it is unclear why, in this study, one is associated with increased odds of obesity among men, while the other is associated with decreased odds.

In the unadjusted models, a higher percentage of calories coming from carbohydrates was negatively associated

What is already known on this subject?

- The few studies that have examined the association between diet composition and obesity have methodological limitations and yield conflicting results.
- No study has investigated the contribution of fats, carbohydrates, protein, and fibre to excess weight among Canadian adults.

What does this study add?

- The number of calories consumed is more important in obesity than is the composition of a diet in terms of the relative percentages of fats, carbohydrates, and protein consumed.
- Dietary fibre is associated with a reduced likelihood of obesity among Canadian men.

with obesity among men. While this is somewhat consistent with an earlier study in which carbohydrate intake remained significant even when adjusted for potential confounders,[7] other research has shown no association between carbohydrate consumption and excess weight.[6,8]

No significant relationship was found in this analysis between obesity and the percentage of calories derived from protein. This is consistent with several cross-sectional studies published in the 1990s.[6-8] A 2006 prospective study found an inverse relationship between protein intake and five-year differences in waist circumference,[44] but a 1999 prospective study found the opposite—a positive relationship between protein intake and body weight.[11]

Dietary fibre has been studied as a preventive factor in the development of obesity. It has been suggested that dietary fibre delays gastric emptying, and thereby contributes to a sensation of fullness.[4] In addition, foods rich in fibre tend to be low in calories.[4] In the present study, dietary fibre was the only nutrient associated with obesity. While the relationship was significant only among men, the odds ratio for women (OR=0.69; CI: 0.45, 1.05) suggests the same direction of association. Previous studies, too, have yielded similar results,[5-7,9] As well, numerous studies have identified fibre as protective against coronary heart disease,[45-48] for which obesity is a risk factor.

The relationships between non-dietary covariates and obesity in the multivariate models are relatively consistent with other studies. Advancing age was associated with increased odds of obesity for both sexes, as were lower levels of education. The odds of obesity were significantly low among women who reported active leisure time, and although not significant among men, the odds ratio was borderline significant (p=.057 for active respondents).

Limitations

This study has a number of limitations. Because the 2004 Canadian Community Health Survey—Nutrition is cross-sectional, causality cannot be inferred. As well, the data pertain to food and beverage consumption for only one day. Results should be interpreted as regression-adjusted averages. The relatively low response rate among individuals with measured height and weight is also a limitation, although the use of the special survey weight adjusted for this shortcoming.

Another limitation is the measure of physical activity, which refers only to leisure time and neglects physical activity related to occupational or educational pursuits and transportation. In addition, the physical activity data were self-reported and so may be subject to recall errors.[49]

As a measure of obesity, BMI is problematic for people who are very muscular or very thin. In addition, BMI does not indicate adiposity on specific areas of the body, which may be associated with health risks (for example, abdominal fat). Nonetheless, BMI is the currently accepted indicator of obesity in epidemiological studies.

Excluding under- and over-reporters may have meant that some respondents who correctly reported their food intake, but consumed significantly more or less than usual that day, were omitted from the analysis. For example, no information was collected about whether respondents were dieting.

On the other hand, the inclusion of only plausible respondents is a strength of this study. Exploratory analyses that included under- and over-reporters found that higher total energy intake was associated with decreased odds of obesity, even controlling for covariates (data not shown). Since energy requirements increase with body weight, this is improbable. Moreover, the technique for identifying plausible respondents used in this study is more sophisticated than those employed in other studies, many of which simply apply an arbitrary range to calories consumed.[6,50] In other studies, under-reporters have also been identified based on the ratio of total energy intake (EI) to basal metabolic rate (BMR); individuals whose EI:BMR ratio is less than 1.2 are typically excluded because such values are rare.[51] However, this method does not take into account the other extreme of the distribution—large values can also be implausible. So despite the exclusion of a substantial number of respondents, compared with other techniques, the one used in this study has the advantage of correcting for under-reporting while ensuring that the characteristics of plausible respondents are representative of the total population.[26]

Conclusion

Results of the present study provide further evidence that it is not what you eat, but rather, how much—the total number of calories consumed—that significantly contributes to obesity. The results also suggest that a diet rich in fibre is associated with a reduced risk of obesity.

This study highlights the importance of adjusting nutrition data for total energy intake and leisure-time physical activity, and especially, identifying and excluding respondents who substantially under-report the number of calories they consume. Restricting the analysis to "plausible" respondents is an important methodological advance; without this correction, the association between calorie consumption and excess weight is lost or distorted.

These results pertain to adults, and it is unclear if they apply to individuals younger than age 18. Given the prevalence of overweight and obesity among young people, future research could usefully examine the association between diet composition and excess weight among children and adolescents. ■

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Appendix

Table A
Adjusted odds ratios relating obesity to selected characteristics, by sex, household population aged 18 or older with plausible energy intake, Canada excluding territories, 2004

	Men			Women		
		95% confidence interval			95% confidence interval	
Characteristics	Adjusted odds ratio	from	to	Adjusted odds ratio	from	to
Nutrient						
Energy intake (in 100s of kilocalories)	1.08*	1.04	1.11	1.15*	1.11	1.20
Carbohydrates (% of energy)	1.01	0.99	1.04	1.02	0.99	1.06
Protein (% of energy)	1.02	0.99	1.06	1.04	0.99	1.08
Saturated fat (% of energy)	0.98	0.92	1.05	1.00	0.94	1.06
Monounsaturated fat (% of energy)	1.10*	1.02	1.18	1.01	0.95	1.08
Polyunsaturated fat (% of energy)	0.88*	0.78	0.99	1.03	0.94	1.14
Fibre (grams per 100 kilocalories)	0.68	0.38	1.21	0.66	0.42	1.03
Age group						
18 to 24†	1.00	...	...	1.00	...	...
25 to 34	2.79	0.93	8.41	2.25	0.94	5.37
35 to 44	2.85	0.90	8.97	2.64*	1.10	6.30
45 to 54	4.92*	1.60	15.11	4.02*	1.53	10.55
55 to 64	5.69*	1.85	17.53	4.06*	1.59	10.41
65 to 74	3.48*	1.07	11.29	3.22*	1.35	7.69
75 or older	2.56	0.73	8.91	2.67*	1.06	6.76
Marital status						
Married/Common-law	0.72	0.38	1.37	1.37	0.71	2.65
Widowed	0.38	0.13	1.09	1.52	0.68	3.39
Separated/Divorced	0.83	0.36	1.94	1.45	0.63	3.36
Never married†	1.00	...	...	1.00	...	...
Education						
Less than secondary graduation	2.49*	1.57	3.93	2.09*	1.20	3.64
Secondary graduation	3.06*	1.82	5.14	1.04	0.67	1.62
Some postsecondary	1.17	0.57	2.42	1.78	0.98	3.22
Postsecondary graduation†	1.00	...	...	1.00	...	...
Household income						
First quintile (lowest)	0.85	0.43	1.68	2.06	0.96	4.43
Second quintile	1.04	0.60	1.83	1.88	0.90	3.92
Third quintile	1.18	0.71	1.96	2.22*	1.12	4.39
Fourth quintile	1.16	0.74	1.81	1.51	0.76	2.99
Fifth quintile (highest)†	1.00	1.00	1.00	1.00	...	...
Missing	0.39*	0.17	0.86	1.34	0.51	3.52
Ethnic origin						
White†	1.00	...	...	1.00	...	...
Aboriginal (off-reserve)	1.41	0.49	4.08	1.86	0.77	4.50
Other	0.28*	0.12	0.69	0.43*	0.20	0.93
Smoking status						
Current smoker	0.59*	0.36	0.99	0.77	0.45	1.33
Former smoker	1.31	0.85	2.01	0.94	0.64	1.39
Never smoked†	1.00	...	...	1.00	...	...
Leisure-time physical activity						
Inactive†	1.00	...	...	1.00	...	...
Moderately active	0.65	0.41	1.02	0.68	0.46	1.00
Active	0.58*	0.35	0.98	0.26*	0.15	0.46

* significantly different from estimate for reference category or from 1.00 for continuous variables ($p<0.05$)
† reference category
... not applicable
Note: Plausible respondents are those whose reported energy intake was 70% to 142% of their predicted energy expenditure.
Source: 2004 Canadian Community Healtgh Survey—Nutrition.