7-2009

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Publication Info

Postprint version. Published in *Journal of the American Dietetic Associaiton*, Volume 109, Issue 7, 2009, pages 1165-1172.

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Published in final edited form as:
J Am Diet Assoc. 2009 July ; 109(7): 1165–1172. doi:10.1016/j.jada.2009.04.002.

Carbohydrate Intake and Overweight and Obesity among Healthy Adults

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Abstract

Background—Little is known about the dietary habits of people with optimal body weight in communities with high overweight and obesity prevalence.

Objective—To evaluate carbohydrate intake in relation to overweight and obesity in healthy, free-living adults.

Design—We used a cross-sectional analysis.

Subjects/setting—The Canadian Community Health Survey Cycle 2.2 is a cross-sectional survey of Canadians conducted in 2004–2005. There were 4,451 participants aged 18 years and older with anthropometric and dietary data and no comorbid conditions in this analysis.

Main outcome measures—Outcome variables were body mass index (BMI; calculated as kg/m^2) and overweight or obesity status (dichotomous) defined as BMI ≥25 compared with BMI <25 based on measured height and weight. Diet was evaluated by 24-hour dietary recall based on the Automated Multi-Pass Method.

Statistical analyses performed—Weighted regression models with bootstrapping and cubic splines were used. Outcome variables were BMI and overweight or obesity, and predictors were daily nutrient intake. Adjustment for total energy intake, age, leisure time energy expenditure, sex, smoking, education, and income adequacy was performed.

Results—Risk of overweight and obesity was decreased in all quartiles of carbohydrate intake compared to the lowest intake category (multivariate odds ratio quartile 2=0.63; 95% confidence interval: 0.49 to 0.90; odds ratio quartile 3=0.58; 95% confidence interval: 0.41 to 0.82; odds ratio quartile 4=0.60; 95% confidence interval: 0.42 to 0.85). Spline analyses revealed lowest risk among those consuming 290 to 310 g/day carbohydrates.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST: No potential conflict of interest was reported by the authors.

Conclusions—Consuming a low-carbohydrate (approximately <47% energy) diet is associated with greater likelihood of being overweight or obese among healthy, free-living adults. Lowest risk may be obtained by consuming 47% to 64% energy from carbohydrates.

Despite rising obesity worldwide, there is no consensus on the best dietary pattern to maintain optimal body weight. High-protein/low-carbohydrate diets bring about greater weight loss in the short-term than diets emphasizing overall energy restriction, but there is no difference between diets in weight loss achieved at the end of 1 year (1). Diets low in whole grain, fiber, fruit and vegetable, and high in *trans* fat are associated with increased risk of overweight and obesity in prospective studies (2,3). However, little is known about the diets of people with optimal body weight in communities with high overweight and obesity prevalence. We therefore evaluated carbohydrate intake in relation to overweight and obesity in a population-based sample of healthy, free-living adults.

METHODS

Study Population

Participants for this analysis were respondents of the Canadian Community Health Survey, Cycle 2.2, a cross-sectional representative sample of free-living Canadians with assessments of height, weight, diet, physical activities, chronic health conditions, smoking, and sociodemographic characteristics (4). Data were collected between January 2004 and January 2005 in all the 10 provinces from people living in private dwellings, with 98% coverage of the target population using a multistage cluster sample (4). The study conformed to the ethical requirements of McMaster University, Hamilton, Ontario, Canada, and Statistics Canada.

Of 35,107 participants in the survey, there were 20,197 participants aged 18 years and older, of whom 11,838 had measured height and weight. Dietary data were considered usable if they were not missing, the participant was able to report the quantity and type of food eaten, and the participant reported that they consumed their usual quantity of food on the day of the assessment. Participants were excluded if their reported caloric intake was outside 1% of the distribution (<560 kcal/day and >6,000 kcal/day). Valid dietary data was obtained from 9,801 participants. Of these, 5,350 participants were excluded because they reported at least one chronic comorbid condition (such as diabetes or cancer), leaving 4,451 healthy adult Canadians for this analysis.

Outcomes

Outcome variables were body mass index (BMI; calculated as kg/m^2) as a continuous variable and also categorized as BMI ≥25, representing the prevalence of overweight or obesity, and <25 otherwise (dichotomous). Well-trained interviewers measured height (cm) to the closest 0.5 cm and weight (kg) to the closest 50 g in all consenting individuals using a standardized protocol for height and weight (4). There were no individuals with BMI <18.5 in our sample.

Nutritional Assessment

Diet—Diet was assessed using a 24-hour dietary recall method based on the Automated Multi-Pass Method developed by the US Department of Agriculture (5,6). Estimates of energy intake from the Automated Multi-Pass Method were more highly correlated with those obtained from doubly labeled water (^2H_2O $H_2{}^{18}O$) (7), and had less bias (8,9) than other methods of diet assessment. An Expert Advisory Group with specialists from Statistics Canada, Health Canada, and US Department of Agriculture modified this method to reflect Canadian foods and be administered in both official languages. The instrument collected information about all the foods and beverages respondents consumed during the 24 hours preceding the day of the interview, from midnight to midnight (4). Approximately one third of respondents of the 24-hour recall were administered the questionnaire for a second randomly chosen day. Detailed information on the adaptation of this method for Canadians and its precision can be found elsewhere (4).

Nutrient Estimation—The Canadian Nutrient File 2007b was used to estimate the nutrient content of foods. This file contains 4,923 foods and 112 nutrients and includes all foods unique to Canada (10). We estimated the mean nutrient intake obtained from the two 24-hour recalls whenever this was available; otherwise we used nutrient estimates from a single 24-hour dietary recall.

Nutrition-Related Variables—Energy-adjusted nutrients, obtained by using the residuals from linear-regression models with the nutrients as outcome variables and total energy intake as the predictor were used. This energy-adjustment procedure reduces extraneous variation in intake associated with age, sex, metabolic efficiency, physical activity, thermogenic effects of foods, and measurement error (11). Moreover, nutrient estimates obtained from such a model can be interpreted as the composition of these substances in the diet independent of the amount of food eaten. Fruit and vegetable intakes were not available in the 24-hour diet data. Statistics Canada derived estimates of fruit and vegetable intake from questions that assessed the frequency of usual intake; the questions appeared in the main questionnaire (4).

Physical Activity—Canadian Community Health Survey, Cycle 2.2 used the Physical Activity Monitor, adapted from the Minnesota Leisure-Time Physical Activity Questionnaire to measure participation in leisure-time physical activity (12). The Physical Activity Monitor had good reliability (r=0.90), and validity when compared with physical activity measured by an alternative questionnaire-based method (r= 0.77), and fair criterion validity (compared with maximal oxygen uptake) (r=0.36) (13). Briefly, participants were asked how many times they participated in up to 24 activities in the past 3 months, and the amount of time they spent on each occasion for each activity. This was multiplied by the energy cost of the activity expressed as kilo-calories expended per kilogram of body weight per hour of activity (kcal/kg/h)/365 to obtain daily metabolic equivalents (METs/day) (14). A physical activity index was calculated based on the total average daily energy expenditure: inactive if <1.5 METs/day, moderately active if 1.5 to 2.9 METs/day, and active if ≥3.0 METs/day.

Other Variables—Income adequacy was a five-level categorical variable derived from total household income and total number of people living in the household (4). Categories were as follows: lowest (reference category), <$10,000 for one to four people or <$15,000 for five or more people; lower, $10,000 to $14,999 for one to two people, $10,000 to $19,999 for three to four people, or $15,000 to $29,000 for five or more people; middle $15,000 to $29,999 for one to two people, $20,000 to $39,999 for three to four people, or $30,000 to $59,999 for five or more people; upper middle $30,000 to $59,999 for one to two people, $40,000 to $79,999 for three to four people, or $60,000 to $79,999 for five or more people; highest ≥$60,000 for one to two people, or ≥$80,000 for three or more people (4). Participants with missing income data were classified as "missing." Education was classified into the following categories: less than secondary school (reference category), secondary school graduation, no post-secondary education, some postsecondary education, and postsecondary degree/diploma. Age was a continuous variable. Smokers were classified into never (reference category), past, and current categories.

Statistical Methods

Statistics Canada calculated a sample weight for each individual based on the survey design, nonresponse, age, and sex within each region, which were used in all estimations. To account for multistage sampling, bootstrap weights (provided by Statistics Canada), were used to estimate confidence intervals for all effect estimates.

To evaluate the relation between carbohydrate intake and potential confounders, energy-adjusted carbohydrate intake was grouped into quartiles. For categorical independent variables, the weighted percentage of individuals in each carbohydrate intake quartile category was reported. For continuous variables, the weighted mean values by quartile of carbohydrate intake were reported.

To evaluate the relation between overweight or obesity and dietary variables, weighted logistic regression models were used, with the prevalence odds ratio of overweight or obesity as the outcome, and each of the nutrient categories as predictors including carbohydrate, fiber, protein, total fat, saturated fat, monounsaturated fat, polyunsaturated fat, and sugar. The multivariate models were adjusted for total energy intake (kcal/day), age (years), leisure time energy expenditure (METs/day), sex, smoking, education, and income adequacy. The Mantel extension test for linear trend used the median value of each nutrient quartile category.

To evaluate the association between intake of carbohydrate and overweight or obesity independent of other nutrients, multivariate logistic regression was used with intake categories of carbohydrate and other nutrients simultaneously included in the model. The simultaneous adjustment of carbohydrate intake and other nutrients was done to account for possible residual confounding.

Analyses were repeated by excluding participants consuming high protein diets (>120 g protein per day or nearly >20% of energy from protein), and high-carbohydrate diets (>59% energy from carbohydrate) in separate multivariate models, to account for overweight or obese individuals that might be adopting diets to lose weight. These analyses were repeated after excluding obese individuals in case these people had changed their diets because they were obese. Finally, the analyses were stratified by age (younger than 55 years vs older), sex, and smoking status. Analyses were done using SAS version 9.0 (2002, SAS Institute, Cary, NC).

To evaluate the relation between continuously measured carbohydrate intake and the prevalence odds ratio of overweight or obesity and BMI we used cubic splines adjusting for the same variables as in the multivariate models (15) using Stata SE version 8.0 (2002, StataCorp LP, Bryan College Station, TX). In all analyses, α was set at .05. These analyses conformed to Statistics Canada's guidelines for research (16).

RESULTS

Participants in the highest carbohydrate intake category were likely to be younger, female, never smokers, and with lower income, as compared with those in the lowest intake category (Table 1). Participants in the highest carbohydrate intake category had lower intakes of total calories, protein, and fats, but more fiber than those in the lowest carbohydrate intake category (Table 2). Sugar intake increased with higher carbohydrate intake, 46 g/day (25% of daily carbohydrate) vs 103 g/day (32% of daily carbohydrate) comparing extreme quartiles of carbohydrate intake. Overweight and obesity prevalence was 65% in quartile 1, 54% in quartile 2, 51% in quartile 3, and 51% in quartile 4.

Carbohydrate intake and overweight and obesity were inversely related after multivariate adjustment. Over-weight and obesity risk was lower by 37% in quartile 2 of carbohydrate intake, 42% in quartile 3, and 40% in quartile 4, compared to the lowest carbohydrate intake category after multivariate adjustment (Table 3). The relation between carbohydrate intake (continuously measured) and overweight or obesity risk was nonlinear after multivariate adjustment (Figure 1). Likelihood of overweight and obesity declined steadily as carbohydrate intake increased until it reached 290 to 310 g/day; when carbohydrate intake was higher than that level the likelihood of overweight or obesity began to rise, but still remained reduced as compared to the lowest carbohydrate intake (Figure 1). There was a curvilinear association between BMI and carbohydrate intake (Figure 2). BMI decreased steadily as carbohydrate intake increased, until it reached the range of approximately 290 to 310 g/day; BMI was lowest at that point. Beyond that level, BMI increased as carbohydrate intake increased (Figure 2). Use of energy-adjusted carbohydrate intake accounted for differences in body-frame size and metabolic efficiency; the simultaneous adjustment for total calories implied substitution of carbohydrate calories for those from protein or fats.

Intakes of fiber, protein, total fat, or its subtypes were not associated with risk of overweight or obesity (data not shown). Intakes of total fruit, vegetables, salad, carrots, potatoes (other than from french fries and chips), other vegetables, and fruit juices were not associated with overweight or obesity (data not shown).

Carbohydrate intake was inversely associated with obesity or overweight when the multivariate model was additionally adjusted for intakes of fiber, protein, total fat, monounsaturated fat, polyunsaturated fat, saturated fat (Table 4), magnesium, fruit, and vegetables.

Analyses excluding people on high-protein or high-carbohydrate diets, or those who were obese were done to evaluate the association between carbohydrate intake and overweight among participants who, most likely, were not trying to lose weight. Higher carbohydrate intake was inversely associated with overweight and obesity comparing extreme intake categories after excluding participants with high protein intake (>120 g/day) (odds ratio [OR]=0.59; 95% confidence interval [CI]: 0.40 to 0.86 comparing the fourth quartile to the first quartile, *P* value test for trend, *P*=0.01), and excluding those with higher carbohydrate intake (>59% calories from carbohydrate) (OR=0.56; 95% CI: 0.32 to 0.98 comparing the fourth quartile to the first quartile, *P* value test for trend, *P*<0.01). Higher carbohydrate intake was inversely associated with overweight after excluding obese participants (OR=0.64; 95% CI: 0.43 to 0.94 comparing the fourth quartile to the first quartile, *P* value test for trend, *P*=0.01). Carbohydrate intake was inversely associated with overweight and obesity among older and younger participants, men and women, and never smokers (data not shown).

CONCLUSIONS

We conducted a cross-sectional study of a population-based sample of healthy, free-living Canadians to examine the relationship between dietary composition and BMI. Risk of overweight and obesity was decreased in all quartiles of carbohydrate intake compared to the lowest intake category. Spline analyses revealed that overweight and obesity risk was lowest among individuals who consumed 290 to 310 g/day carbohydrates (ranging from 47% to 64% of calories from carbohydrates), after accounting for age, sex, income, education, leisure-time physical activity, and total energy intake.

Overweight and obesity develops when there is a positive caloric imbalance, and is impacted by genes and the environment (17). There is no consensus on the best dietary pattern to maintain optimal body weight, but multiple clinical trials have compared different dietary compositions in relation to weight loss (1,18). Data from these clinical trials show that low-carbohydrate diets are more effective at inducing weight loss in the short-term (6 months) than high-carbohydrate diets, but there is no difference in their efficacy at the end of 1 year (1). There is also evidence that the Mediterranean diet (approximately 40% energy from fat, high in whole grains, fruit, and vegetables) is as effective as low-carbohydrate and low-fat diets in weight reduction over 2 years (18). These studies evaluated diets in relation to weight loss, and not the diets of free-living individuals. Thus, our study provides needed data on the association between dietary composition, in particular carbohydrate intake, and risk of overweight and obesity among a healthy, free-living population.

Overall diet quality, together with physical activity, is related to weight maintenance. Energy-dense foods are rich in refined carbohydrates and unhealthy fats. Snack-food items and soft drinks make up the majority of energy-dense foods (19), while energy density is low in fruits and vegetables, poultry, fish, and whole grains (20). In one study, participants who ate more fruit and vegetable were less obese (and had lower energy density diets) whether or not their diets were high-fat (>30% calories from fat) or low-fat (≤30% calories from fat) compared with people who ate fewer fruit and vegetables (21). People consuming more energy-dense foods (20) and less whole grains (22) are more likely to have higher BMI than those doing otherwise. In our study, participants were least likely to be overweight or obese and had lowest BMI if they consumed between 47% and 64% of calories from carbohydrates. Participants consuming more carbohydrate ate more fruit and vegetables, fiber, and less saturated fat than those consuming less carbohydrate.

Overweight and obesity are risk factors for cardiovascular disease, and diet quality is also important in predicting cardiovascular disease (16). In previous studies, the diet composition of groups with lower overweight and obesity was generally consistent with the American Heart Association dietary recommendations to minimize low-density lipoprotein cholesterol (23), and Health Canada’s Food Guide (24). Overall, participants in our study ate less fiber [13 to 22 g/day on average for the four levels of carbohydrate intake, vs the recommendation of 38 g/day for men and 25 g/day for women (24,25)], and more saturated fat (7% to 14% vs the recommended <7% kcal energy from saturated fat). Thus, efforts to increase fiber and reduce saturated fat intakes, perhaps by avoiding energy-dense foods (26), may provide important health benefits in this population.

A limitation of our data was that there was no information on carbohydrate type (simple or complex). In general diets composed mainly of simple carbohydrates, such as sugar, have deleterious health consequences, while diets made up mostly of complex carbohydrates are favorable for health (27). Complex carbohydrates are a broad group of carbohydrates that are rich in soluble and insoluble fiber and include whole grain (27). Whole grain contains a number of substances with potentially favorable health benefits, such as antioxidants, phytoestrogens, and fiber (28), and is associated with lower energy intake (3), improved metabolic profile, and lower risk of obesity (29), central adiposity (3), diabetes, and cardiovascular disease (30). According to one estimate, Canadians consume less than one whole-grain serving per day on average (31) and, as mentioned previously, participants in our study consumed less than the recommended levels of fiber, on average. We attempted to examine the effect of carbohydrates on overweight or obesity independent of fiber using multivariate modeling. As fiber intake is correlated with whole grain in the diet, this model indirectly assessed the association between refined grain and overweight and obesity. Carbohydrate intake remained inversely associated with risk of overweight or obesity with fiber in the model.

A second limitation of these data was that only leisure-time physical activity was assessed. Residual confounding because of unmeasured utilitarian and job-related activity was possible. Even so, participants in quartile 3 of carbohydrate intake (having lowest overweight and obesity risk) were more physically active than those in the lowest and highest carbohydrate intake categories, underscoring the central role of physical activity in relation to body weight. Third, as the study design was cross-sectional, diet, height, and weight were measured at the same time. It is possible that the participants had changed their diets as a result of being overweight or obese, and that few people consuming very low- and very high-carbohydrate diets were driving the associations. To minimize these biases, participants who reported chronic health conditions because of which they may have altered their diets, were excluded. In addition, the analyses were repeated excluding participants who reported high-protein and high-carbohydrate intakes because they may be trying to lose weight, or those who were obese. Results did not materially change in these analyses. Fourth, diet was assessed by 24-hour recall, which is a measure of recent food intake. Ten days or more of data are usually needed to get accurate estimates of usual intake from 24-hour dietary recalls (32). To overcome this limitation, participants who reported that they ate more or less food than their usual intake on the day of the dietary assessment and those with implausible dietary intake were excluded; an average of two dietary recalls were used when these data were available (for about one third of participants). Moreover, recent (24-hour dietary data) and usual dietary intakes (from food frequency questionnaire) are correlated (33). Because energy-adjusted nutrients were used, it was possible to assess diet composition, minimizing extraneous variation associated with age, sex, and measurement error (11). Total energy intake was not associated with overweight and obesity risk probably because the error associated with measuring total energy intake in epidemiological studies is greater (34) than the calories sufficient to cause overweight (17). However, it is still possible to observe an association between overweight and obesity and diet composition because the latter is more accurately measured by dietary assessment methods used in epidemiological studies (35).

It is challenging to find a statistical model that accurately captures the true association between carbohydrate intake and overweight and obesity. Traditional regression models impose the assumption that the relation between carbohydrate intake and overweight and obesity is linear, which may be incorrect. One option to overcome the strong linearity assumption is to categorize the exposure, as we did in these analyses. A drawback of this method is that because the data are grouped into categories, the relation at the extremes of the distribution may be misspecified. Yet another option is to use nonlinear regression methods, such as multivariate splines. The two main advantages of this technique are that it does not impose an assumption about the distribution of the association being evaluated (linear or otherwise) and it allows use of continuous (not grouped) data, overcoming the main limitations of more traditional multivariate methods. Results from the spline analyses suggest that the relation between carbohydrate intake and overweight and obesity prevalence is nonlinear. However, because of the potential for residual confounding by physical activity and the lack of more detailed information about carbohydrate type, our results need to be interpreted with caution and replicated in other data sets.

Carbohydrate intake was inversely associated with risk of overweight or obesity in this sample of free-living, healthy Canadians. Lowest risk of overweight or obesity was found among those consuming between 190 to 310 g/day carbohydrates (equal to between 47% and 64% calories from carbohydrate). Individuals with higher carbohydrate intake ate more fruits and vegetables and fiber, and less saturated fat, and a higher percentage reported being physically active, than those consuming less carbohydrate. Thus, this population may benefit by consuming whole grain instead of refined grain, more fiber, less saturated fat, fewer calories, and by remaining physically active.

Acknowledgments

FUNDING/SUPPORT: There was no external funding for this study.

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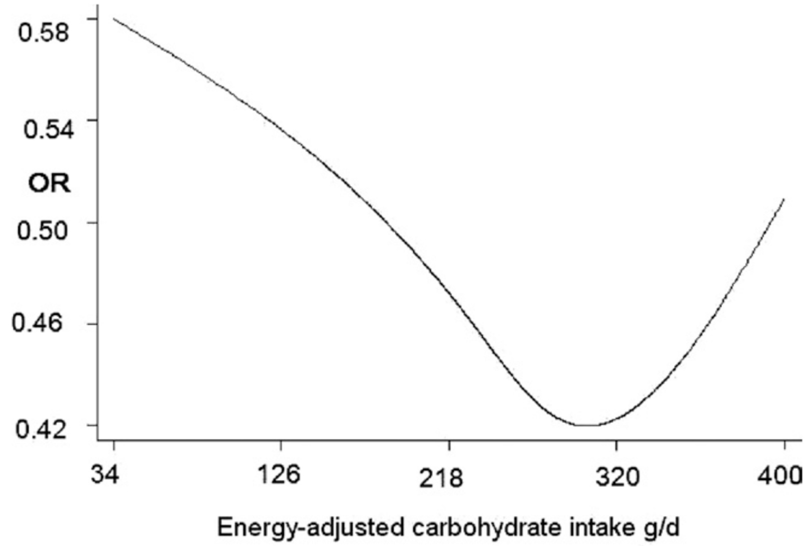

Figure 1.

Multivariate association of continuously measured carbohydrate intake and overweight and obesity risk (OR) in adult participants of the Canadian Community Health Survey, Cycle 2.2, 2004. Spline model, adjusted for total energy intake (kcal/d), age (year), leisure time energy expenditure (metabolic equivalents/week), sex, smoking (never, past, and current), education (less than secondary, secondary, other postsecondary, postgraduate), income adequacy (lowest, lower middle, upper middle, highest, not stated). Note that the axes do not start at 0.

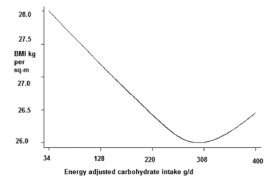

Figure 2.

Multivariate association between continuously measured carbohydrate intake and body mass index (BMI; calculated as kg/m^2) in adult participants of the Canadian Community Health Survey, Cycle 2.2, 2004. Spline model, adjusted for total energy intake (kcal/d), age (year), leisure time energy expenditure (metabolic equivalents/week), sex, smoking (never, past, and current), education (less than secondary, secondary, other postsecondary, postgraduate), income adequacy (lowest, lower middle, upper middle, highest, not stated. Note that the axes do not start at 0.

Table 1

Characteristics of healthy, adult participants of the Canadian Community Health Survey, Cycle 2.2, 2004 by quartiles of carbohydrate intake[a]

	Carbohydrate Intake			
	Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
	median			
Age (y)	41	38	40	36
	%			
Males[b]	55	57	55	49
Income adequacy[c]				
Lowest	5	8	6	11
Lower middle	14	16	18	21
Upper middle	37	31	31	31
Highest	36	37	34	29
Not stated	7	8	10	8
Highest education level				
Less than secondary	14	15	14	15
Secondary	23	18	17	16
Other postsecondary	9	10	8	9
Postgraduate	55	58	61	61
Smoker				
Never	38	48	54	62
Former	26	25	26	17
Current	36	27	20	31
Leisure time physical activity	*mean*			
Daily energy expenditure (METs[d])	1.7	1.9	1.8	1.7
Frequency of all physical activity	1.7	1.5	1.6	1.6
Monthly frequency, physical activity >15 min	19	23	21	21
Physical activity index	*%*			
Active (<1.5 METs/d)	16	22	22	18
Moderate (1.3–2.9 METs/d)	26	25	24	24
Inactive (≥3.0 METs/d)	58	53	53	58

[a]Data based on weighted mean and frequency estimates (n=4,451).

[b]Note all percentages are based on columns and add up to 100. Differences are due to rounding. A separate category for female is not provided because it is redundant.

[c]Income adequacy. Lowest, <$10,000 for one to four people or <$15,000 for five or more people [reference]; lower, $10,000–$14,999 for one to two people, $10,000–$19,999 for three to four people, or $15,000–$29,000 for five or more people; middle $15,000–$29,999 for one to two people, $20,000–$39,999 for three to four people, or $30,000–$59,999 for five or more people; upper middle, $30,000–$59,999 for one to two people, $40,000–$79,999 for three to four people, or $60,000–$79,999 for five or more people; highest, ≥$60,000 for one to two people, or ≥$80,000 for three or more people (4).

[d]MET=metabolic equivalent.

Table 2

Dietary characteristics of healthy, adult participants of the Canadian Community Health Survey, Cycle 2.2, 2004 by quartiles of carbohydrate intake[a]

	Carbohydrate Intake			
Mean values	**Quartile 1**	**Quartile 2**	**Quartile 3**	**Quartile 4**
Energy (kcal/d)	2,214	2,313	2,303	2,140
Fiber (g/d)[b]	13	17	18	22
Carbohydrate (g/d)[b]	179	234	269	319
Sugar (g/d)[b]	46	63	76	103
% Sugar in carbohydrate	25	27	28	32
Protein (g/d)[b]	104	88	79	70
Total fat (g/d)[b]	88	76	68	54
Monounsaturated fat (g/d)[b]	35	30	27	21
Polyunsaturated fat (g/d)[b]	15	14	12	10
Saturated fat (g/d)[b]	30	25	22	16
% Energy from protein	21	18	16	14
% Energy from carbohydrate	36	47	54	64
% Energy from fat	40	35	31	24
% Energy from saturated fat	14	11	10	7
% Energy from polyunsaturated fat	7	6	5	5
% Energy from monounsaturated fat	16	14	12	9
Fruit intake frequency per day[c]	1.0	1.1	1.2	1.4
Salad per day[c]	0.5	0.5	0.4	0.5
Potatoes per day[cd]	0.3	0.3	0.3	0.3
Carrots per day[c]	0.3	0.3	0.3	0.4
Other vegetables[c]	1.1	1.1	1.0	1.3
Total fruit and vegetables per day[c]	3.9	4.1	4.2	4.9

[a]Based on weighted mean intake (n=4,451).

[b]Energy-adjusted intake from 24-hour dietary recall.

[c]From main questionnaire evaluating frequency of usual intake (number of times per day).

[d]Other than french fries and chips.

Table 3

Multivariate association of carbohydrate intake and overweight or obesity in healthy, adult participants of the Canadian Community Health Survey, Cycle 2.2, 2004[abc]

Quartile	Odds ratio	95% Confidence interval	*P* value test for trend
2 Carbohydrate	0.63	0.49–0.90	
3 Carbohydrate	0.58	0.41–0.82	
4 Carbohydrate	0.60	0.42–0.85	<0.01

[a]Adjusted for total energy intake (kcal/d), age (year), leisure time energy expenditure (metabolic equivalents/week), sex, smoking (never, past, and current), education (less than secondary, secondary, other postsecondary, postgraduate), income adequacy (lowest, lower middle, upper middle, highest, not stated) (n=4,451) (weighted).

[b]Quartile 1 reference, from weighted logistic regression model with overweight and obesity as the outcome, confidence intervals obtained by bootstrapping.

[c]Overweight or obese, body mass index (calculated as kg/m^2) ≥25.

Table 4

Multivariate association of carbohydrate intake and overweight or obesity with simultaneous adjustment for other nutrients in healthy, adult participants of the Canadian Community Health Survey, Cycle 2.2, 2004[ab]

Quartile	Odds ratio	95% Confidence interval	*P* value test for trend
2 Carbohydrate	0.65	0.46–0.92	
3 Carbohydrate	0.59	0.41–0.85	
4 Carbohydrate	0.61	0.42–0.87	0.01
2 Fiber	0.93	0.66–1.32	
3 Fiber	0.80	0.54–1.17	
4 Fiber	0.96	0.66–1.38	0.64
2 Carbohydrate	0.65	0.46–0.92	
3 Carbohydrate	0.61	0.42–0.88	
4 Carbohydrate	0.64	0.45–0.91	0.01
2 Protein	1.00	0.70–1.43	
3 Protein	1.08	0.77–1.51	
4 Protein	1.15	0.80–1.65	0.42
2 Carbohydrate	0.61	0.42–0.88	
3 Carbohydrate	0.52	0.35–0.77	
4 Carbohydrate	0.48	0.30–0.76	<0.01
2 Total fat	0.82	0.56–1.20	
3 Total fat	0.73	0.48–1.12	
4 Total fat	0.69	0.44–1.12	0.05
2 Carbohydrate	0.64	0.45–0.93	
3 Carbohydrate	0.59	0.40–0.87	
4 Carbohydrate	0.59	0.38–0.91	0.01
2 Monounsaturated fat	0.89	0.63–1.27	
3 Monounsaturated fat	0.86	0.57–1.31	
4 Monounsaturated fat	0.97	0.65–1.46	0.70
2 Carbohydrate	0.63	0.45–0.90	
3 Carbohydrate	0.58	0.41–0.84	
4 Carbohydrate	0.59	0.40–0.87	0.01
2 Polyunsaturated fat	0.77	0.55–1.07	
3 Polyunsaturated fat	0.91	0.65–1.28	
4 Polyunsaturated fat	0.91	0.62–1.33	0.68
2 Carbohydrate	0.63	0.44–0.90	
3 Carbohydrate	0.56	0.39–0.79	
4 Carbohydrate	0.55	0.37–0.82	<0.01
2 Saturated fat	1.05	0.74–1.48	
3 Saturated fat	0.80	0.55–1.14	
4 Saturated fat	0.88	0.60–1.29	0.19

[a]Logistic regression model (weighted), adjusted for total energy intake (kcal/d), age (year), leisure time energy expenditure (metabolic equivalents/week), sex, smoking (never, past, and current), education (less than secondary, secondary, other postsecondary, postgraduate), income adequacy (lowest, lower middle, upper middle, highest, not stated).

[b]Quartile 1 reference in all comparisons.

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