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- . not available for any reference period
- .. not available for specific reference period
- ... not applicable
- p preliminary
- r revised
- x suppressed to meet the confidentiality requirements of the Statistics Act
- E use with caution
- F too unreliable to be published

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Why does the social gradient in health not apply to overweight?

by Stefan Kuhle and Paul J. Veugelers

Abstract

Background
In developed countries, there is a negative association between socioeconomic status (SES) and a variety of health outcomes, known as the social gradient in health. This is contrasted by a weak, absent or even positive gradient for overweight. The objective of this study was to investigate why overweight does not follow the social gradient.

Data and methods
Data from adult respondents to the 2004 Canadian Community Health Survey (cycle 2.2) were used. A series of multivariate models regressing overweight and determinants of overweight on household education and household income were performed, stratified by gender.

Results
Except for education among women, negative associations between SES measures and overweight emerged. Respondents from higher household income groups reported more meals away from home, compared with those from lower household income groups. In addition, adults in higher-education households were more likely than those in lower-education households to have quit smoking.

Interpretation
Differences in food consumption patterns and smoking cessation between SES groups may have contributed to the lack of a clear negative association between household education and income and overweight in the CCHS.

Keywords
body weight, dietary habits, education, income, nutrition, physical activity, smoking, socio-economic factors

Authors
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One of the paradigms of public health is that in developed countries, individuals of lower socio-economic status (SES) tend to have poorer health. Numerous studies have demonstrated a higher prevalence of risk factors for cardiovascular diseases[1] and type 2 diabetes,[2] a higher incidence of cardiovascular disease[3] and some cancers,[4] and higher all-cause,[5] cardiovascular[6] and cancer mortality[7] in lower SES groups. This phenomenon, commonly known as the "social gradient," may reflect the fact that lower SES is associated with barriers in access to quality health care; environmental exposures; and limitations in knowledge, time and opportunity for making healthy lifestyle choices.[8]

Findings are less consistent when the outcomes are overweight and obesity. A seminal review by Sobal and Stunkard in 1989 found that associations between SES and obesity in women followed the social gradient in the majority of studies, but for men, half of studies reported an absent (17%) or even reversed (30%) gradient.[9] Similar, albeit less striking, figures were reported in a 2007 update of the review.[10]

Survey data from a number of industrialized countries continue to show a negative association between SES and overweight/obesity for women and an inconsistent relationship for men.[11-19] Studies that compared national data longitudinally found that over the past decades, the prevalence of obesity has increased faster in the highest SES groups than in lower SES groups.[11,19] This coincided with the surge in the overall prevalence of obesity.[11]

Recent data from Canada show that the SES gradient for overweight/obesity is associated with gender.[20,21] Univariate analyses of Public Use Microdata from the 2004 Canadian Community Health Survey (CCHS) revealed no discernible association between household income and obesity among women, but a positive association among men. A negative association between education and obesity was observed for women, but not for men.

To date, there is only speculation about why the social gradient is less pronounced for overweight/obesity and why gender differences exist. Smoking cessation, alcohol intake and chronic illness have been suggested as potential confounders,[9] but no previous study has conducted an in-depth analysis of this counter-intuitive phenomenon.

The richness and high quality of the CCHS data offer an opportunity to examine a number of hypotheses about these unexpected findings. The objective of the present paper is to investigate associations that may underlie the blurred or positive gradient between SES and overweight, and also gender differences, by assessing the distribution of risk factors for overweight across SES groups. Being able to explain these findings may further understanding of the causes and consequences of the high levels of obesity in the Canadian population.

Hypotheses

Four *a priori* hypotheses were formulated.

Hypothesis I: *Higher SES groups more frequently have meals prepared outside the home, have higher total calorie intake, and have lower fruit and vegetable consumption than do lower SES groups.*
Rationale: While higher SES groups have traditionally had a better-quality diet, changes in time available for meals and for food preparation over the last two decades [22,23] may have altered SES differences in diet quality. For example, owing to time constraints faced by dual-earner families, members of higher-income households may eat meals prepared outside the home more often than do members of lower-income households. Such meals are typically high in fat and calories and low in fruits and vegetables.

Hypothesis II: *Higher SES groups are less physically active than lower SES groups.*
Rationale: Technological advances during recent decades, notably computerization, entertainment technology and automated transport, have reduced physical activity.[22] If these technologies are more affordable to and more readily adopted by higher SES groups, this would decrease their physical activity.

Hypothesis III: *Members of higher SES groups are more likely than those in lower SES groups to quit smoking.*
Rationale: Smoking cessation has been reported to increase the likelihood of becoming obese.[24] If smoking cessation campaigns have been more successful among higher SES groups, this may have increased the prevalence of overweight in these groups.

Hypothesis IV: *Neighbourhood factors confound the association between SES and overweight.*
Rationale: A number of studies have shown that area-level factors are important for the development of obesity.[13,25,26] The built environment facilitates physical activity that may be associated with obesity.[27] Recreational spaces and facilities, neighbourhood walkability and safety, healthy food choices, and peer role model behaviour adoption may be more common in wealthier neighbourhoods.

Methods

Data source

The current study used data from the 2004 Canadian Community Health Survey (CCHS), cycle 2.2. The CCHS is a nationally representative cross-sectional survey assessing demographics, health, social environment, physical activity, nutrition (24-hour dietary recall), and anthropometric measures (height and weight). The survey excluded residents of the territories, Indian Reserves, Canadian Forces bases, institutions, and some remote areas.

The area frame of the Canadian Labour Force Survey, a multi-stage stratified cluster design, was used to select participating households. One respondent per household was chosen using probabilities of selection that vary by age and by sampling frame. A detailed description of the sampling strategy is available elsewhere.[28] Interviews were conducted from January 2004 through the entire calendar year. The overall response rate was 76.5%. A total of 35,107 individuals participated in the survey, 21,160 of whom were aged 18 or older. The current study uses data from 12,428/21,160 (59%) adult respondents for whom anthropometric measures were available. Information from participants with measured height and weight was obtained by face-to-face interviews.

Definitions

Socioeconomic factors

Household income, highest level of household education, average area-level household income, and age (range 18 to 101 years) were used as covariates, based on *a priori* assumptions about confounding.

Household income was considered as a four-level categorical covariate that accounts for the number of people in the household and total household income from all sources in the 12 months before the interview[29]: lowest (less than $15,000 if one or two people; less than $20,000 if three or four people; less than $30,000 if five or more people); lower-middle ($15,000 to $29,999 if one or two people; $20,000 to $39,999 if three or four people; $30,000 to $59,999 if five or more people); upper-middle ($30,000 to $59,999 if one or two people; $40,000 to $79,999 if three or four people; $60,000 to $79,999 if five or more people); highest ($60,000 or more if one or two people; $80,000 or more if three or more people).

Household education was used as a three-level categorical covariate representing the highest level of educational attainment in the household (secondary graduation or less; some postsecondary education or college diploma; university degree).

Statistics Canada 2001 Census Division (CD) areas were used as proxies for neighbourhoods. *Area-level household income* was used as a proxy for neighbourhood SES.

Outcomes

Overweight, low fruit and vegetable intake, total daily energy intake, eating out, low physical activity and former smoker were assessed in separate regression models. Detailed information about the underlying survey variables is available elsewhere.[29]

Overweight

Height and weight were directly measured using standardized procedures and calibrated instruments. Body mass index (BMI) was calculated as weight in kilograms/height in metres squared. Respondents were classified as normal weight (BMI less than 25 kg/m^2) or overweight (BMI greater than or equal to 25 kg/m^2).

Low fruit and vegetable intake

Self-reported consumption of fruit/vegetables was assessed using an adapted version of the Behavioral Risk Factor Surveillance System[30] frequency of fruit and vegetable consumption module. Respondents were classified according to whether their reported intake of fruit/vegetables was less than five versus five or more times per day.

Total daily energy intake

Total daily calorie intake (continuous) was determined as the sum of all energy intakes (in kilocalories) from food sources reported in the first 24-hour dietary recall component of the CCHS.

Eating out

Based on data from the first 24-hour dietary recall, respondents were classified as those who had consumed at least one meal that had not been prepared at home and those who had not.

Because total energy intake and eating out are based on the first of two dietary recalls, the results represent nutrition habits only *on the day of the survey*.

Low physical activity

Low physical activity was assessed as a binary variable based on the physical activity index,[31] which takes into account the frequency, duration and intensity of self-reported leisure-time physical activity. Respondents whose physical activity index was less than 1.5 kcal/kg/day were classified as having a low level of physical activity.[29]

Former smoker

Based on self-reports, respondents were classified as current smokers, former smokers, or never smokers. To enable logistic regression analysis for this outcome, smoking status was dichotomized (former versus current smokers); never smokers were omitted from this model.

Statistical analysis

Associations between the above outcomes and socio-economic factors were examined using linear (total daily calorie intake) or logistic regression (all other outcomes). To harmonize the interpretation of the linear and logistic regression models, linear regression coefficients were exponentiated to represent the relative risk (and 95% confidence interval) for a 1,000-calorie increase in total daily energy intake.[32, 33] Age (continuous variable), age-squared, household income and household education were considered simultaneously in the models. To adjust for the confounding effect of age, age was used as a continuous covariate with a quadratic term, thereby accounting for the peak in the prevalence of overweight around the sixth decade of life.

Household income from 2001 Census income data was standardized and divided into quartiles, and then linked to the CCHS data at the Census Division (CD) level. The influence of neighbourhood income on the odds of being overweight was examined using multilevel regression methods. Respondents (individual level, n=12,428) were nested within CD areas (area level, n=274); average household income quartiles were used as an area-level covariate. To assess between-neighbourhood variation, the intraclass correlation coefficient (ICC) was calculated using the latent variable approximation.[34]

Because associations between SES and the outcomes were expected to differ between men and women,[20, 21] all analyses were stratified by gender. Information about household income and household education was missing for 9% and 2% of adult respondents, respectively. Missing values were considered as separate covariate categories, but the results are not presented.

Estimates were obtained using sampling weights provided by Statistics Canada to account for design effect and non-response bias. Standard errors were estimated using a bootstrapping procedure.[35,36] However, bootstrap weights could not be applied to the multilevel models; standard errors for these models are, therefore, likely biased, and results must be interpreted with caution. Stata Version 9 (Stata Corp, College Station, TX, USA) was used to perform the statistical analyses.

Results

The descriptive statistics for CCHS respondents aged 18 or older whose height and weight were directly measured are shown in Table 1. The coefficients of variation for the prevalence estimates in Table 1 were all below the 16% cut-off (indicating acceptable sampling variability) recommended by Statistics Canada.[28]

In 2004, 53% of women and 65% of men were overweight. The majority of adults (68%) consumed fruit and vegetables fewer than five times a day and were physically inactive (58%).

Among women, in both the unadjusted and adjusted analyses, a strong inverse association was evident between household education and overweight, but not between household income and overweight (Table 2).

Among men, in both the unadjusted and adjusted analyses, a positive association emerged between overweight and household income, but no gradient could be discerned in the relationship between household education and overweight (Table 2).

Hypothesis I (eating habits)

The social gradient persisted for fruit and vegetable consumption, with the frequency of consumption tending to rise with household education and income for both sexes, although it was not statistically significant among men (Table 3). By contrast, for calorie consumption, no clear gradient for either SES measure was apparent, except that women in the highest household education category had significantly higher intake. However, adults from higher-income households were significantly more likely than those in lower-income households to report having had a meal on the recall day that had not been not prepared at home.

Table 1
Selected characteristics of adults with measured height and weight in 2004 Canadian Community Health Survey, cycle 2.2

	Total (n=12,428)	Women (n=7,176)	Men (n=5,252)
Mean total energy intake (kilocalories per day)	2,145	1,829	2,468
		%	
Overweight	59	53	65
Obese	23	23	23
Low fruit/vegetable intake (consumption less than 5 times per day)	68	63	74
Eating out (at least one meal per day prepared outside the home)	53	51	55
Low physical activity (less than 1.5 kilocalories/kilogram/day)	58	60	55
Smoking status			
Current smoker	25	23	28
Former smoker	27	24	31
Never smoker	47	53	41
Age			
18 to 24	13	12	14
25 to 34	16	16	16
35 to 44	21	21	22
45 to 54	20	20	20
55 to 64	14	14	14
65 or older	16	17	14
Education			
Secondary gratuation or less	21	21	20
Some postsecondary or college diploma	44	44	45
University degree	33	33	33
Household income			
Lowest	9	10	7
Lower-middle	19	21	18
Upper-middle	33	32	35
Highest	30	28	33

Source: 2004 Canadian Community Health Survey: Nutrition.

Hypothesis II (physical activity)

For physical activity, the social gradient was present for household education among women, and for household income among men, with lower SES groups being more likely to report a low level of activity (Table 3).

Hypothesis III (smoking)

For women, the odds of being a former rather than current smoker were significantly greater for those in higher education and higher income households (Table 3). By contrast, smoking cessation was generally not significantly associated with household education or income among men.

Hypothesis IV (neighbourhood)

Adjusting the overweight model for average area-level household income did not change the associations between household education and income and overweight for either sex (Table 2). The variance attributable to between-neighbourhood variations in household income was 5% in women and 8% in men.

Discussion

The results of the current study are in keeping with recent international data, which have found a negative association between SES and overweight/obesity for women and an inconsistent relationship for men.[11,12,14-19] The analyses presented here expand on previous findings by using directly measured (as opposed to self-reported) height and weight, thereby eliminating reporting bias, and by providing an in-depth look at associations underlying the narrowed or reversed social gradients for overweight.

We had hypothesized that greater calorie consumption in higher SES groups could potentially explain the narrowed or reversed social gradients for overweight. However, except for a positive association with education

Table 2
Adjusted and unadjusted odds ratios relating socio-economic factors to overweight, by sex, household population aged 18 or older, Canada excluding territories, 2004

	Women									Men								
	Univariate			Multivariate†			Multilevel multivariate‡			Univariate			Multivariate†			Multilevel multivariate‡		
	Odds ratio	95% confidence interval from	to	Odds ratio	95% confidence interval from	to	Odds ratio	95% confidence interval from	to	Odds ratio	95% confidence interval from	to	Odds ratio	95% confidence interval from	to	Odds ratio	95% confidence interval from	to
Education																		
Low	2.17*	1.69	2.77	1.89*	1.42	2.51	1.76*	1.40	2.21	1.18	0.88	1.58	1.25	0.90	1.74	0.95	0.68	1.34
Middle	1.78*	1.41	2.26	1.81*	1.42	2.32	1.84*	1.45	2.33	0.88	0.67	1.16	0.94	0.70	1.26	0.78	0.60	1.01
High§	1.00	...	...	1.00	...	...	1.00	...	..	1.00	...	..	1.00	...	...	1.00	...	...
Household income																		
Lowest	1.07	0.76	1.51	0.89	0.61	1.30	0.99	0.72	1.36	0.54*	0.33	0.91	0.51*	0.28	0.90	0.58*	0.42	0.80
Lower-middle	1.39*	1.05	1.84	1.10	0.81	1.50	1.18	0.89	1.57	0.66*	0.47	0.94	0.63*	0.43	0.92	0.62*	0.41	0.93
Upper-middle	1.10	0.86	1.40	0.94	0.73	1.22	0.92	0.72	1.16	0.69*	0.51	0.93	0.72*	0.52	0.99	0.80	0.58	1.11
Highest§	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Area-level household income																		
Lowest§	1.00	...	...	...	...	...	1.00	...	...	1.00	...	...	...	...	...	1.00	...	...
Lower-middle	0.65*	0.61	0.69	...	...	...	1.48*	1.24	1.78	0.83*	0.75	0.91	...	...	...	0.86*	0.76	0.98
Upper-middle	0.52*	0.49	0.57	...	...	...	0.65*	0.55	0.78	1.05	0.95	1.16	...	...	...	1.04	0.93	1.16
Highest	0.62*	0.59	0.66	...	...	...	0.87	0.73	1.03	0.73*	0.66	0.80	...	...	...	0.74*	0.65	0.84

† adjusted for household education, household income, age and age squared
‡ adjusted for average area-level household income, household education, household income, age and age squared
§ reference category
* significantly different from estimate for reference category ($p < 0.05$)
... not applicable
Source: 2004 Canadian Community Health Survey: Nutrition.

among women, no clear gradient in the associations between SES and total energy intake emerged. Moreover, the association of both household education and household income with fruit and vegetable consumption followed the traditional gradient, with lower SES groups being less likely to consume fruit and vegetables.

There was a strong positive association between household income and eating out, which has gained attention as a potential contributor to the rising prevalence of obesity. In recent decades, food establishments, in particular fast-food outlets, have seen unprecedented growth, catering to the demand for time-saving food preparation.[37] For example, from 1990 to 2006, restaurant revenues in Canada more than doubled, rising from $16.5 billion to $34.4 billion.[38] People who often eat out tend to consume more calories[39,40] and to have a higher BMI[41] than do those who usually eat home-prepared meals. Thus, greater frequency of eating out among higher income groups may be associated with the inverse gradient between household income and overweight among men, but it does not explain the gender differences. As well, this contrasts with the lack of a social gradient for total energy intake. However it is possible that estimates of energy intake for meals eaten out are subject to error because respondents lack detailed knowledge about the food they consumed.

We had further hypothesized that higher SES groups had lower levels of leisure-time physical activity than did lower SES groups, possibly because they can more readily afford computers and entertainment technology, which foster sedentary behaviour. Nonetheless, higher SES groups actually tended to be more physically active during their leisure time. It may be that their greater leisure-time physical activity is counterbalanced by sedentary activity in the workplace.[42,43] He *et al.* reported that lower leisure-time physical activity rates among lower education groups were offset by more strenuous activity at work, resulting in an overall similar total energy expenditure across education groups.[44]

A number of studies have reported associations between smoking cessation and weight gain.[24,45-47] We had hypothesized that members of higher SES groups are more likely than those in lower SES groups to quit smoking, and that this could be associated with a higher prevalence of overweight (Hypothesis III). And indeed, the analyses showed a strong positive association between SES and smoking cessation. Thus, smoking cessation may, in part, account for the lack of a clear gradient for SES and overweight. Although some studies did not observe gender differences in weight gain after smoking cessation,[24,45,48] two reported greater gains among men than among women.[49,50] This could explain the

Table 3
Adjusted odds ratios and risk ratios relating socio-economic factors to determinants of overweight , by sex, household population aged 18 or older, Canada excluding territories, 2004

	Low fruit/vegetable intake (less than 5 times per day)			Total daily energy intake			Eating out (at least one meal prepared outside the home)			Low physical activity (less than 1.5 kilocalories/ kilogram/day)			Smoking cessation		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
	Odds ratio	from	to	Risk ratio	from	to	Odds ratio	from	to	Odds ratio	from	to	Odds ratio	from	to
Women															
Household education															
Low	1.74*	1.26	2.40	0.81*	0.73	0.90	0.99	0.75	1.30	1.71*	1.27	2.32	0.33*	0.20	0.54
Middle	1.29*	1.00	1.68	0.90*	0.82	0.99	1.08	0.83	1.39	1.34*	1.04	1.72	0.53*	0.34	0.81
High†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Household income															
Lowest	1.60*	1.01	2.53	0.97	0.87	1.07	0.52*	0.36	0.75	1.26	0.85	1.86	0.48*	0.29	0.78
Lower-middle	1.56*	1.07	2.26	0.99	0.89	1.10	0.64*	0.47	0.87	1.51*	1.10	2.08	0.60*	0.37	0.98
Upper-middle	1.14	0.84	1.53	1.02	0.93	1.13	0.75*	0.58	0.97	1.04	0.80	1.35	0.79	0.51	1.24
Highest†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Men															
Household education															
Low	1.45	0.98	2.15	1.14	0.95	1.38	0.83	0.60	1.15	1.21	0.87	1.67	0.47*	0.29	0.78
Middle	1.21	0.89	1.65	1.23*	1.08	1.42	0.89	0.67	1.18	1.01	0.77	1.33	0.69	0.45	1.07
High†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Household income															
Lowest	1.84*	1.05	3.22	0.87	0.67	1.12	0.49*	0.31	0.78	2.31*	1.43	3.71	0.55	0.27	1.11
Lower-middle	1.16	0.76	1.79	0.84*	0.70	0.99	0.52*	0.37	0.73	1.94*	1.37	2.74	0.58*	0.36	0.94
Upper-middle	1.43*	1.04	1.96	0.95	0.83	1.10	0.69*	0.51	0.92	1.64*	1.25	2.48	0.89	0.62	1.27
Highest†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...

† reference category
* significantly different from estimate for reference category ($p < 0.05$)
Note: Models are adjusted for household education, household income, age and age squared. Results for Total daily energy intake represent the risk of a 1,000-calorie higher energy intake, compared with reference category.
Source: 2004 Canadian Community Health Survey: Nutrition.

gender differences in the association between SES and overweight.

In the past decade, neighbourhood characteristics have received attention as determinants of an individual's body weight.[13,25,26] We hypothesized that neighbourhood SES confounds the association between SES and overweight (Hypothesis IV). Our multilevel analyses, however, do not support this hypothesis. The low percentage of variance attributable to neighbourhood factors may be because Statistics Canada's Census Divisions are not "functional" neighbourhoods, given that their average size is about 110,000 people. Yet even based on smaller clusters (Census Subdivisions, average size ~ 5,500), the variance explained by area-level factors did not change substantially. It is possible that area-level income is not the optimal measure of neighbourhood factors that are relevant for health-related behaviours.

The cross-sectional design of the study makes it difficult to determine if the blurred/reversed gradient represents a new phenomenon or if it has always been present. As early as the 1960s through the 1980s, survey data reported gender differences in the association between SES and overweight/obesity.[51-54] Longitudinal data from large representative surveys such as the NHANES in the US show marked changes in the association between SES and obesity coinciding with the increase in the prevalence of obesity during the period just before NHANES III (1988 to 1994).[11,19] Similarly, Canadian data from the Heart Health Surveys (1986 through 1992)[55] found a negative association between income and obesity for both sexes. The greatest increase in obesity prevalence since the late 1980s was among men in higher income groups; the prevalence of obesity in the lowest income group was virtually unchanged. Shifts in the association between SES measures and overweight/obesity are now consistently seen in other developed countries as well.[12-18] Differing gender role expectations may, in part, be responsible for paradoxical associations. While male overweight/obesity is considered acceptable, excess body weight in females is more socially undesirable.[56]

What is already known on this subject?

- Individuals of lower socio-economic status (SES) tend to have poorer health, a phenomenon commonly referred to as the social gradient of health.
- Associations between SES and overweight/obesity are less consistent and show gender differences.
- The lifestyle factors related to SES that may underlie this observation have not been investigated.

What does this study add?

- Differences between SES groups in food consumption patterns and smoking cessation may be associated with the lack of a strong negative association between SES measures and overweight.

Limitations

Socio-economic status is a complex construct that is determined by income, education, occupation, family background, and place of residence. In practice, SES is measured with indicators such as income, educational attainment, occupational status, or composite indices. Any social gradient may be influenced by the indicator used, and none may capture the full meaning of the construct.

The two SES indicators in the current study—household education and household income—have shortcomings. Because both were measured at the household rather than the individual level, it was not possible to determine if these indicators differed for men and women in a given household.

Income commonly has more missing values than education and is less constant over time. Another challenge in the use of income as a proxy for SES is that the association between income and overweight may operate in the reverse direction; that is, obesity may reduce labour market success. Finally, the dollar values assigned to the higher household income categories in the CCHS may not represent monetary wealth in some locations, thereby potentially misclassifying respondents' SES. On the other hand, a disadvantage of education as an indicator of SES is that some groups like immigrants or visible minorities may be underpaid relative to their educational background.

The self-reported measures used in this analysis, notably, total calorie intake and the frequency of fruit and vegetable consumption, have inherent limitations, and these results should be interpreted with caution.

Conclusion

The strength of the current study is that BMI is based on physical measures, as opposed to the self-reported anthropometric data in other studies. Also, the broad scope of the CCHS enabled an in-depth analysis of associations between household education and income and various lifestyle determinants of overweight. However, the study is limited by its cross-sectional design and the self-reported nature of the data.

The results of the current study confirm research from other developed countries showing that the social gradient for overweight is reduced or, in the case of income in men, even reversed. The current study found some evidence that differences in food consumption patterns and smoking cessation between SES groups may have contributed to this finding. ■

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Beverage consumption of children and teens

by Didier Garriguet

Abstract

According to results from the 2004 Canadian Community Health Survey – Nutrition, children and teens get about one-fifth of their daily calories from beverages. As they get older, boys and girls drink less milk and fruit juice, and more soft drinks and fruit drinks. By ages 14 to 18, boys' average daily consumption of soft drinks matches their consumption of milk, and exceeds their consumption of fruit juice and fruit drinks. Beverage consumption by children and teens varies little by province, except in Newfoundland and Labrador where it tends to be comparatively high, and in British Columbia where it tends to be low.

Keywords

carbonated beverages, energy intake, milk, water consumption

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A substantial proportion of Canadians' daily calories come not from what they eat, but from what they drink. This is particularly true for children. According to results from the 2004 Canadian Community Health Survey (CCHS) – Nutrition (see *The data*), beverages make up almost 20% of the calories consumed by children and teens aged 4 to 18 (Table 1). At ages 1 to 3, beverages account for an even higher 30%.

Liquids, notably water, are essential to good nutrition. While some water comes from foods, most is derived from beverages. As well, beverages provide vitamins and minerals. However, beverages can also be a major source of sugar, and may contribute to excess calories. Sugar-sweetened drinks have been linked to weight gain and higher body mass index in children and teenagers.[1] Sweetened drinks, and even fruit juice, have been associated with an increased risk of tooth decay.[2]

This article is an overview of beverage consumption by Canadian children and teens aged 1 to 18. It examines the quantity and type of beverages consumed, differences by age and gender, and beverages' contribution to calorie and nutrient intake.

Water

More than 85% of all the beverages consumed by children and teens fall into five categories: water, milk, fruit juice, fruit drinks, and regular soft drinks.

Table 1
Percentage of daily calories derived from beverages, by gender and age group, household population aged 1 to 18, Canada excluding territories, 2004

Age group	Boys	Girls
	percent	
1 to 3	28.2	27.3
4 to 8	20.8*†	18.1†
9 to 13	18.1†	18.0
14 to 18	20.0†	19.0

* significantly different from estimate for girls of same age ($p < 0.05$)
† significantly different from estimate for same sex in preceding age group ($p < 0.05$)
Source: 2004 Canadian Community Health Survey – Nutrition.

Table 2
Percentage who consumed selected beverages the previous day, by gender and age group, household population aged 1 to 18, Canada excluding territories, 2004

	Water		Milk		Fruit juice		Regular soft drinks		Fruit drinks	
Age group	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
	percent									
1 to 3	71	71	87	88	62	58	8	6	29	28
4 to 8	72*	79†	80*†	71†	54†	49†	19†	17†	45†	41†
9 to 13	74	78	68†	64†	43†	43†	33†	29†	45	47†
14 to 18	77	74	60*†	53†	39	40	53*†	35†	35†	34†

* significantly different from estimate for girls of same age ($p < 0.05$)
† significantly different from estimate for same sex in preceding age group ($p < 0.05$)
Source: 2004 Canadian Community Health Survey – Nutrition.

On a typical day, at least 70% of children and teens drink water (Table 2). The amount consumed rises steadily with age (Table 3). At ages, 1 to 3, children drink less water than milk, but by ages 4 to 8, the amounts are equal, and at ages 14 to 18, teens drink more water than any other beverage: an average of 780 grams a day for boys and 694 grams for girls. (In the CCHS, all beverages are reported in grams. Compared with volume, one gram of water is equal to one millilitre of water. Most beverages are slightly heavier than water, in the order of 1% or 2%.)

Milk

Drinking milk is generally associated with childhood. Indeed, milk makes up almost half of the beverages consumed by children aged 1 to 3, who average more than 450 grams a day (Table 3), or about one and three-quarters servings from the "Milk Products" group of Canada's Food Guide to Healthy Eating.[3] Consumption drops at older ages, and starting at age 4, boys drink more milk than girls do. Boys' daily consumption stabilizes at about one and a third servings of milk a day, but for girls, a second drop occurs in adolescence, with average daily consumption falling to less than one serving at ages 14 to 18.

The decline in milk consumption at older ages is attributable to fewer consumers rather than to less milk consumed by those who drink it (Table 2). While 87% of boys and 88% of girls aged 1 to 3 drank milk the day before the CCHS interview, at ages 14 to 18, the figures were 60% for boys and 53% for girls.

Fruit juice

Average daily fruit juice consumption is relatively stable among children and teens, varying between 171 and 200 grams for boys, and between 147 and 168 grams for girls (Table 3). At ages 1 to 8, boys drink more fruit juice than do girls. These amounts are equivalent to one and a half servings from the "Vegetables and Fruit" group of the Food Guide for boys, and one and a quarter servings for girls.

The overall stability in average daily intake hides the fact that at older ages, smaller proportions of children and teens drink fruit juice (Table 2). Around 60% of 1- to 3-year-olds had fruit juice the day before the CCHS interview; at ages 14 to 18, the figure was about 40%. The stability in average consumption for children and teens is due to greater consumption by those

Table 3
Average daily consumption (in grams) of selected beverages, by gender and age group, household population aged 1 to 18, Canada excluding territories, 2004

	Total beverages		Water		Milk		Fruit juice		Regular soft drinks		Fruit drinks	
Age group	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
	grams											
1 to 3	1,069*	994	248	238	459	450	200*	168	18[E]	13[E]	96	81
4 to 8	1,184*†	1,022	337†	337†	338*†	272†	194*	157	68*†	47†	161*†	134†
9 to 13	1,505*†	1,299†	509†	483†	332*	267	171	147	152*†	109†	211†	192†
14 to 18	2,121*†	1,666†	780*†	694†	323*	222†	192	165	376*†	179†	198	175

* significantly different from estimate for girls of same age ($p < 0.05$)
† significantly different from estimate for same sex in preceding age group ($p < 0.05$)
E use with caution (coefficient of variation 16.6% to 33.3%)
Source: 2004 Canadian Community Health Survey – Nutrition.

Table 4
Average daily consumption (in grams) by those who consumed selected beverages the previous day, by gender and age group, household population aged 1 to 18, Canada excluding territories, 2004

	Water		Milk		Fruit juice		Regular soft drinks		Fruit drinks	
Age group	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
	grams									
1 to 3	349	337	528	509	325	290	237E	205E	327	292
4 to 8	466†	428†	423*†	381†	360*	318	358*†	270	361	330
9 to 13	692†	623†	485*†	414	402*†	343	457*†	380†	468*†	412†
14 to 18	1,015†	938†	537*†	421	489*†	417†	715*†	514†	574†	510†

* significantly different from estimate for girls of same age ($p < 0.05$)
† significantly different from estimate for same sex in preceding age group ($p < 0.05$)
E use with caution (coefficient of variation 16.6% to 33.3%)
Source: 2004 Canadian Community Health Survey – Nutrition.

who continued to drink fruit juice at older ages, particularly 14- to 18-year-olds (Table 4).

Sweetened beverages

At older ages, children's beverage consumption increases and becomes more varied. Water, milk and fruit juice account for about 85% of the beverages consumed by children aged 1 to 3, but at ages 14 to 18, the figure is just over 60%. Sweetened beverages—soft drinks and fruit drinks with less than 100% juice—make up most of the difference.

Consumption of sweetened beverages increases with age: more children choose these beverages, and those who drink them drink more. This is particularly true for regular soft drinks. Fewer than 10% of children aged 1 to 3 had a regular soft drink the day before the CCHS interview, but at ages 14 to 18, the percentages were 53% for boys and 35% for girls (Table 2). Boys' average daily consumption of regular soft drinks climbs from 68 grams at ages 4 to 8 to 376 grams at ages 14 to 18; among girls, the rise is from 47 to 179 grams (Table 3). Moreover, among soft drink consumers, average daily intake is slightly more than 200 grams at ages 1 to 3, but at ages 14 to 18, 715 grams for boys and 514 grams for girls (Table 4).

Consumption of fruit drinks peaks at ages 9 to 13, with boys averaging 211 grams a day, and girls, 192 grams (Table 3). However, among those who consume fruit drinks, daily intake is highest at ages 14 to 18, averaging more than 500 grams (Table 4).

In addition to water, milk, fruit juice and sweetened drinks, Canadian children and teens drink other beverages such as vegetable juice, tea and coffee. However, the amounts consumed tend to be relatively small (Appendix Table A).

Calories, sugar and nutrients

Beverages are an important source of energy for children and teens, supplying up to 30% of daily calories. Sugar in fruit juice (fructose) and milk (lactose) provide calories. As well, milk contains

Figure 1
Percentage of daily calories derived from sweetened drinks and from milk and fruit juice, by gender and age group, household population aged 1 to 18, Canada excluding territories, 2004

† regular soft drinks and fruit drinks
Source: 2004 Canadian Community Health Survey – Nutrition.

The data

The data are from the 2004 Canadian Community Health Survey (CCHS) – Nutrition, which was designed to collect information about the food and nutrient intake of the household population. The CCHS excludes members of the regular Canadian Forces and residents of the three territories, Indian reserves, institutions and some remote areas, as well as all residents (military and civilian) of Canadian Forces bases. Detailed descriptions of the CCHS design, sample and interview procedures are available in a published report.[4]

This article is based on data from the "24-hour dietary recall" component of the 2004 CCHS. Respondents were asked to list all foods and beverages consumed during the 24 hours before the day of their interview (midnight to midnight). Interviewers used the "Automated Multi-pass Method,"[5,6] with a five-step approach to help respondents remember what they had to eat and drink:

- quick list (respondents reported all foods and beverages consumed in whatever order they wished);
- questions about specific food categories and frequently forgotten foods;
- questions about the time of consumption and type of meal (for example, lunch, dinner);
- questions seeking more detailed, precise descriptions of foods and beverages and quantities consumed; and
- a final review.

A subsample of the population responded to a second 24-hour recall a few days later to help assess day-to-day variations in food and beverage intake. Information for children younger than 6 was collected from their parents, and interviews for children aged 6 to 11 were conducted with parental help. When parents were unable to provide details (for example, foods and/or beverages eaten at daycare or at school), they were asked to get as much information as possible from those who had been in charge of their children. The energy and nutrient content of the food and beverages was derived from Health Canada's Canadian Nutrient File 2001b, Supplement.[7]

A total of 35,107 people completed the initial 24-hour dietary recall, and a subsample of 10,786 completed the second recall three to ten days later. Response rates were 76.5% and 72.8%, respectively. A total of 128 recalls were excluded for various reasons: invalid or "null" recalls, breastfeeding children and children younger than age 1. The first 24-hour recall for 14,493 children and teens aged 1 to 18 years was used for this study. The bootstrap method, which takes into account the complex survey design, was used to estimate standard errors, coefficients of variation, and confidence intervals.[8,9] The significance level was set at $p < 0.05$.

The beverage categories are based in groupings created by Health Canada's Bureau of Nutritional Sciences. Recipes and basic foods have separate categories. The categories were revised to eliminate double-counting. Beverages used in food recipes belonging to a non-beverage food category (milk in a cake recipe, for example) are excluded from the beverage categories.

The *water* category refers to municipal, bottled, well and distilled water consumed as such. It excludes water required to prepare another beverage (for instance, water in coffee is included in the coffee category).

The *milk* category includes all milk regardless of fat content, evaporated milk and milk added to tea or coffee. It also includes goat milk and infant formulas. Condensed milk and milk added to ready-to-eat or hot cooked cereals (on average, 45 grams of milk daily) are excluded.

The *fruit juice* category refers to 100% pure juice, and includes the juice portion of alcoholic beverages and juice recipes (concentrate and water). *Fruit and vegetable juice* is a different category, separate from *fruit juice* and also from *vegetable juice.*

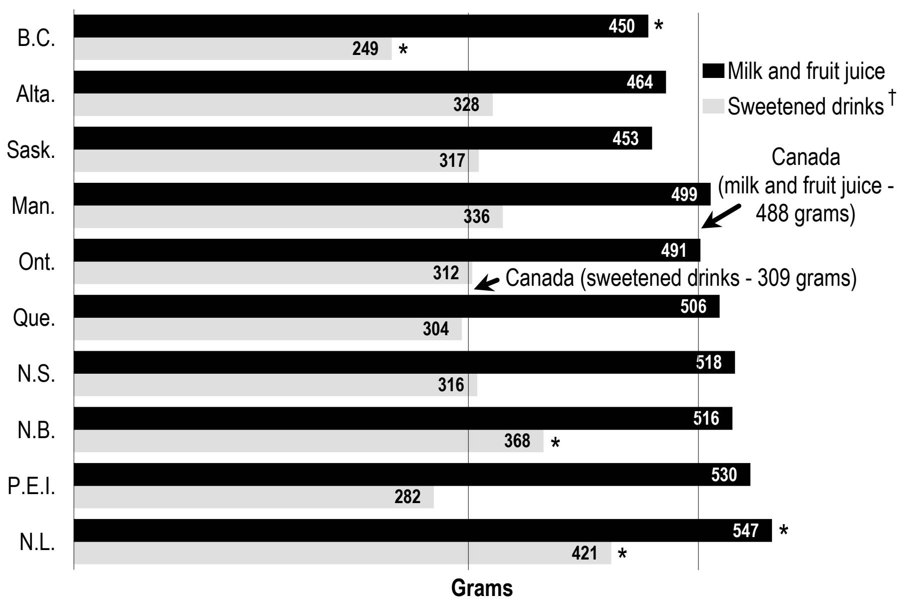
The *fruit drinks* category comprises beverages that contain less than 100% fruit juice. Together, *fruit drinks* and *regular soft drinks* make up the *sweetened beverages* category.

Total beverages includes all of the above categories, as well as *tea* and *coffee* (excluding added items such as cream), *milk-based beverages* (mix of milk and a powder, eggnog, and milkshakes), *other types of milk* (soy and rice beverages, buttermilk), *diet soft drinks*, *beer* (alcoholic and non-alcoholic), *spirit*, *liqueurs*, *wine,* and *coolers*.

The methods used to gather information about food and beverage consumption are generally associated with some under-reporting. The 24-hour dietary recall is not immune to this problem, even when the Automated Multiple-pass Method, which maximizes respondent recall, is used. Another report[10] estimated calorie under-reporting at close to 10% for CCHS respondents aged 12 or older. Under-reporting of beverages will strongly correlate with that of energy.

It is possible that some traces of a beverage category are found in another category in cases where it is impossible to separate certain ingredients in a mixture.

Figure 2
Average daily consumption (in grams), by type of beverage and province, household population aged 1 to 18, Canada excluding territories, 2004



* significantly different from estimate for Canada ($p < 0.05$)
† regular soft drinks and fruit drinks
Source: 2004 Canadian Community Health Survey – Nutrition.

lipids in the form of saturated fats. Calories from fruit drinks and soft drinks come mostly from added sugars.

During early childhood, milk and fruit juice contribute far more daily calories than do sweetened drinks. The gap narrows as children get older, and almost evens out at ages 14 to 18 (Figure 1). Although this shift is not reflected in total calories derived from beverages, it affects the contribution of beverages to vitamin and mineral intake.

Fruit juice alone contributes substantially to children's requirements for vitamin C. Depending on their age, children obtain 50 mg to 72 mg of vitamin C a day from fruit juice, well above the estimated requirement of 13 mg to 63 mg.[11] However, an estimated 7% of Canadian adolescents are deficient in vitamin C.[12]

Milk accounts for a considerable share of children's and teens' daily intake of vitamins and minerals: vitamin D (45% to 69 %), calcium (29% to 51%), vitamin B_{12} (21% to 48%), vitamin A (21% to 35%), riboflavin (19% to 40%), phosphorus (17% to 37%), potassium (13% to 30%) magnesium (11% to 27%), and zinc (9% to 25%) (data not shown). The steady drop in girls' milk consumption in older age groups is of concern, as a significant proportion of adolescent girls have inadequate intake of vitamin A, magnesium and zinc, and low intakes of potassium and calcium.[3,13]

Interprovincial differences

Children's and teens' beverage consumption varies little from one province to another. However, compared with the Canadian average, beverage consumption is significantly high in Newfoundland and Labrador (Figure 2), particularly of fruit juice by children younger than 9 and of regular soft drinks by 9- to 18-year-olds (data not shown). On the other hand, beverage consumption in British Columbia is significantly below the Canadian average. ■

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Appendix Table A
Average daily consumption (in grams) of selected beverages, by age group and gender, household population aged 1 to 18, Canada excluding territories, 2004

	1 to 3		4 to 8		9 to 13		14 to 18	
Beverage	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
	grams							
Total beverage consumption	**1,069**	**994**	**1,184**	**1,022**	**1,505**	**1,299**	**2,121**	**1,666**
Water	248	238	337	337	509	483	780	694
Milk	459	450	338	272	332	267	323	222
Milk-based beverages	18	13E	39	40	42	34	44	36
Other types of milk	18E	10E	F	F	6E	F	F	3E
Fruit juice	200	168	194	157	171	147	192	165
Fruit drinks	96	81	161	134	211	192	198	175
Regular soft drinks	18E	13E	68	47	152	109	376	179
Diet soft drinks	F	F	4E	6E	24E	17	16	37
Vegetable juice	F	F	F	F	8E	F	F	8E
Tea	7E	F	31E	15	44	39	80	80
Coffee	F	F	F	F	4E	3E	37	48

E use with caution (coefficient of variation 16.6% to 33.3%)
F too unreliable to be published
Note: Fruit and vegetable juice and alcoholic beverages (beer, spirit, wine, cooler) are included in total beverage consumption.
Source: 2004 Canadian Community Health Survey – Nutrition.

Beverage consumption of Canadian adults

by Didier Garriguet

Abstract

According to results from the 2004 Canadian Community Health Survey—Nutrition, total beverage consumption among adults declined steadily with age. This reflects drops in the percentage of adults consuming most beverages and in the amounts consumed. While water was the beverage consumed most frequently and in the greatest quantity by adults, for many of them, coffee ranked second. Largely as a result of drinking coffee, more than 20% of men and 15% of women aged 31 to 70 exceeded the recommended maximum of 400 milligrams of caffeine per day. About 20% of men aged 19 to 70 consumed more than two alcoholic drinks a day. Owing to declines in the consumption of soft drinks and alcohol, the contribution of beverages to adults' total calorie intake falls at older ages. Regardless of age, men were generally more likely than women to report drinking most beverages, and those who did, drank more. There were, however, a few exceptions, with higher percentages of women than men reporting that they drank water and tea.

Keywords

alcohol drinking, caffeine, carbonated beverages, coffee, energy intake, milk, water consumption

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Fluid intake, notably water, is essential for good health.[1] Water plays a role in almost all body functions and is a major component of every cell, tissue and organ. It regulates temperature, transports oxygen and nutrients through the blood, helps get rid of waste, and provides a medium for biological reactions. Water is important for the digestion and absorption of food. It lubricates joints and moistens tissue in the eyes, mouth and nose.

The result of insufficient intake is dehydration, which can contribute to a number of health problems. Over the age of 65, thirst tends to diminish,[2] and individuals are unlikely to drink without consciously thinking about it. Dehydration, in fact, is one of the most frequent causes of hospitalization of elderly people.

While some water comes from solid food, most of it comes from beverages, either as plain water or as part of other beverages such as coffee, tea and soft drinks.

Beverages also make up an important component of nutrition. They contribute to healthy eating by helping to meet Food Guide[3] recommendations for the consumption of dairy products and vegetables and fruits. But beverages, especially those rich in added sugar such as soft drinks, may take individuals over recommended levels for calorie consumption. As well, beverages are responsible for excess intake of caffeine and alcohol.

This article is an overview of beverage consumption among Canadians aged 19 or older. Based on data from the 2004 Canadian Community Health Survey—Nutrition (CCHS), the analysis examines the type and quantity of beverages consumed, highlighting differences by age and sex. The information from the 2004 CCHS makes it possible to study Canadians' beverage consumption, a topic about which relatively little is known.

All nutrient information from the CCHS, and consequently, in this article, is reported in grams. A gram of water is roughly the equivalent of one millilitre of water.

Consumption declines with age

Adults' total beverage consumption drops steadily with age. In 2004, daily beverage consumption of 19- to 30-year-olds averaged 2,610 grams for men and 2,056 grams for women (Table 1). For people aged 71 or older, the figures were substantially lower, at 1,584 grams and 1,532 grams, respectively.

Water

Water (excluding water in other drinks and foods) was the beverage consumed in the greatest quantity by the greatest number of Canadian adults. The day before they were interviewed, 77% of men and 84% of women aged 19 to 30 drank water, consuming averages of 1,360 and 1,194 grams (Table 2). The proportion of women reporting that they drank water did not change at older ages, but among men, the figure fell to 65% at age 71 or older. However, for both sexes, the average amount of water consumed declined among seniors to 774 grams for men and 799 grams for women. As a result, daily water consumption for the total population aged 71 or older (both consumers and non-consumers) averaged 500 grams for men and 654 grams for women (Table 1).

Coffee, caffeine and tea

After water, the beverage that the largest proportion of adults reported consuming the day before they were interviewed tended to be coffee (Table 2). In fact, men older than age 50 were more likely to report having had coffee than water. The exception to the trend toward coffee was 19- to 30-year-olds, who were more likely to report having had milk the previous day. As well, the proportion of men in this age group who reported having had regular soft drinks exceeded the proportion who had coffee.

Among those who drank coffee, consumption peaked at ages 31 to 50, averaging 639 grams for men and 586 grams for women. By age 71 or older, the average amounts were considerably lower at 489 grams and 398 grams.

Coffee accounted for almost all the caffeine that adults consumed: 80.6%. (Tea and soft drinks made up 12.3% and 5.9%.) Caffeine has a number of biological effects resulting from its diuretic and stimulant properties. For some sensitive individuals, these can include restlessness, anxiety, irritability, muscle tremors, insomnia, headaches and abnormal heart rhythms. Health Canada advises healthy adults to limit their daily caffeine intake to 400 milligrams,[4,5] the equivalent of three 8-ounce cups of coffee.

More than 20% of men and around 15% of women in the 31-to-70 age range exceeded the 400 milligram per day recommendation (Figure 1). Not surprisingly, the age and sex patterns of caffeine intake parallelled those of coffee.

Contrary to the trend for most beverages, the proportion of Canadians who reported drinking tea rose steadily with advancing age. Among men, the increase was from 20% at ages 19 to 30 to 49% at age 71 or older; for women, from 30% to 56%. And unlike many other beverages, the amount of tea consumed remained relatively stable regardless of age. For example, among male tea drinkers, 19-to-30-year-olds consumed an average of 525 grams;

Table 1
Average daily consumption (in grams) of selected beverages, by age group and gender, total household population aged 19 or older, Canada excluding territories, 2004

	19 to 30		31 to 50		51 to 70		71 or older	
	Men	Women	Men	Women	Men	Women	Men	Women
	Grams							
Total beverage consumption	**2,610*†**	**2,056†**	**2,345*†**	**2,206†**	**2,051*†**	**1,891†**	**1,584†**	**1,532†**
Water	1,045	1,000	861*†	1,065	705*†	840†	500*†	654†
Coffee	227*	183	451*†	375†	474*	364	365*†	270†
Tea	105*	136	131*†	178†	174*†	227†	246†	262†
Regular soft drinks	304*	142	193*†	97†	115*†	62†	37†	29†
Diet soft drinks	32	44	61†	69†	53	55	39E*	13E†
Beer	300*	54	232*†	49	174*†	36E	69E*†	9E†
Wine	19E	18E	28	36†	52*†	34	27†	20†
Spirits and liquor	8E	8E	7E	6E	8*	2E†	7E*	2E
Milk	201	178	158†	154	133†	120†	166	136
Milk-based beverages	42E	30	17E†	16†	11E	18E	6E†	8E†
Other types of milk	F	8	6E	8E	4E*	8E	F	5 E
Fruit juice	176*	136	108*†	86†	98	80	76†	84
Vegetable juice	10	10	15	12	20	13	12	8
Fruit drinks	135	107	77*†	55†	31†	34†	31	32

* significantly different from estimate for women of same age ($p < 0.05$)
† significantly different from estimate for same sex in preceding age group ($p < 0.05$)
E use with caution (coefficient of variation 16.6% to 33.3%)
F suppressed because of extreme sampling variability (coefficient of variation greater than 33.3%)
Note: Fruit and vegetable juice and coolers are included in total beverage consumption.
Source: 2004 Canadian Community Health Survey – Nutrition.

Table 2
Percentage who consumed selected beverages the previous day and their average daily consumption (in grams), by age group and gender, household population aged 19 or older, Canada excluding territories, 2004

	19 to 30		31 to 50		51 to 70		71 or older	
Beverage	Men	Women	Men	Women	Men	Women	Men	Women
Percentage who consumed beverage (%)								
Water	77*	84	77*	84	72*†	82	65*†	82
Coffee	40	39	71*†	64†	79*†	74†	75*	68†
Tea	20*	30	27*†	35†	33*†	47†	49*†	56†
Regular soft drinks	47*	27	32*†	21†	22*†	15†	12†	10†
Diet soft drinks	6*	8	9*†	13†	11	12	8*	4^{E}†
Beer	26*	8	26*	8	21*†	6†	12*†	2^{E}†
Wine	5^{E}	6	8*†	13†	17†	15	13	11†
Spirits and liquor	5	5	6	4	8*	3	9*	3
Milk	49	54	57†	61†	56	58	64†	69†
Milk-based beverages	7	8	4†	5†	3	4	2^{E}	3^{E}
Other types of milk	1^{E}*	3^{E}	2^{E}*	3^{E}	2^{E}*	3	2^{E}	2^{E}
Fruit juice	34	34	28†	29	32	33	35	38†
Vegetable juice	2^{E}	4^{E}	4^{E}	5^{E}	6	5	5	4
Fruit drinks	22	22	15†	14†	8†	10†	13†	12
Average daily consumption (grams)								
Water	1,360*	1,194	1,121*†	1,270	974†	1,027†	774†	799†
Coffee	574 *	473	639†	586†	599 *	490†	489*†	398†
Tea	525 *	452	486	501	527	486	507	468
Regular soft drinks	649 *	534	598*	465	519*†	406	321†	305†
Diet soft drinks	577	533	697 *	532	479†	445†	487^{E}	319†
Beer	1,159 *	704	908*†	590	829 *	607	567†	452
Wine	402	291^{E}	340 *	265	304 *	223†	198†	178†
Spirits and liquor	158	173^{E}	112	146^{E}	100 *	68†	78	60
Milk	408*	328	276*†	253†	239*†	206†	260	198
Milk-based beverages	572^{E}	366	381	315	333	401	233	264†
Other types of milk	297^{E}	281	394^{E}*	223	226†	235	229^{E}	217
Fruit juice	523 *	401	382*†	293†	310*†	245†	221†	221†
Vegetable juice	417 *	253	342	260	318^{E}	252	236	216
Fruit drinks	610 *	496	497*†	391†	369†	326	236†	257†

^{E} use with caution (coefficient of variation 16.6% to 33.3%)
* significantly different from estimate for women of same age ($p < 0.05$)
† significantly different from estimate for same sex in preceding age group ($p < 0.05$)
Note: Fruit and vegetable juice and coolers are included in total beverage consumption.
Source: 2004 Canadian Community Health Survey – Nutrition.

those aged 71 or older averaged 507 grams.

Soft drinks

Adults' consumption of regular soft drinks drops sharply at older ages. While close to half of men (47%) and over a quarter of women (27%) aged 19 to 30 reported having consumed regular soft drinks the previous day, by age 71 or older, the figure was around 10% for both sexes. Also, the quantity consumed fell in successively older age groups. For instance, male soft drink consumers aged 19 to 30 averaged 649 grams, about twice the intake of those aged 71 or older (321 grams).

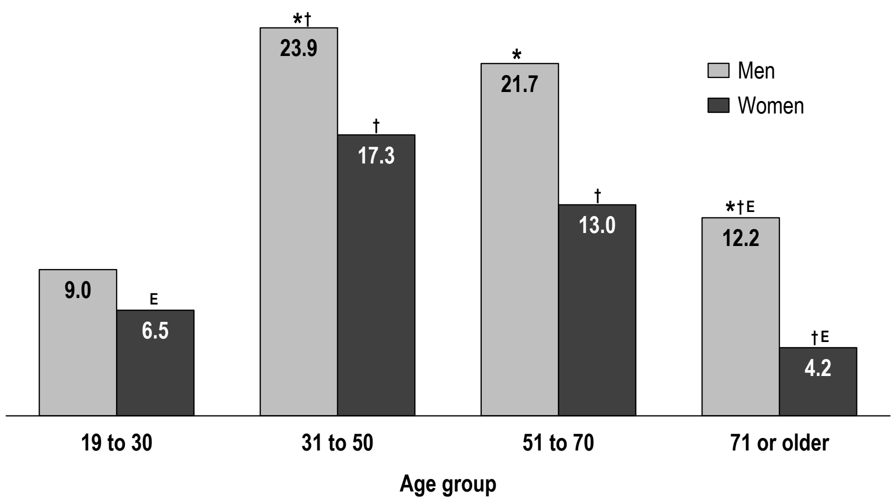
Relatively few adults reported drinking diet soft drinks. The highest proportion was around 10% at ages 31 to 70. However, those who had diet soft drinks tended to drink just as much as those who reported consuming regular soft drinks. For example, women aged 19 to 30 who reported consuming diet soft drinks drank an average of 534 grams; those who reported regular soft drinks drank an average of 533 grams.

Alcoholic beverages

Because alcohol consumption varies considerably depending on the occasion, it is difficult to determine a "usual" level. As well, alcohol consumption is subject to under-reporting.[6] The Centre for Addiction and Mental Health has established guidelines for low-risk drinking: a maximum of 14 drinks a week for men and 9 drinks a week for women, and no more than two drinks per occasion.[7] While the proportions exceeding these weekly recommendations cannot be determined from the CCHS, it is possible to calculate daily alcohol intake. At ages 19 to 70, about 20% of men and 8% of women reported usually consuming more than two drinks per day (Figure 2).

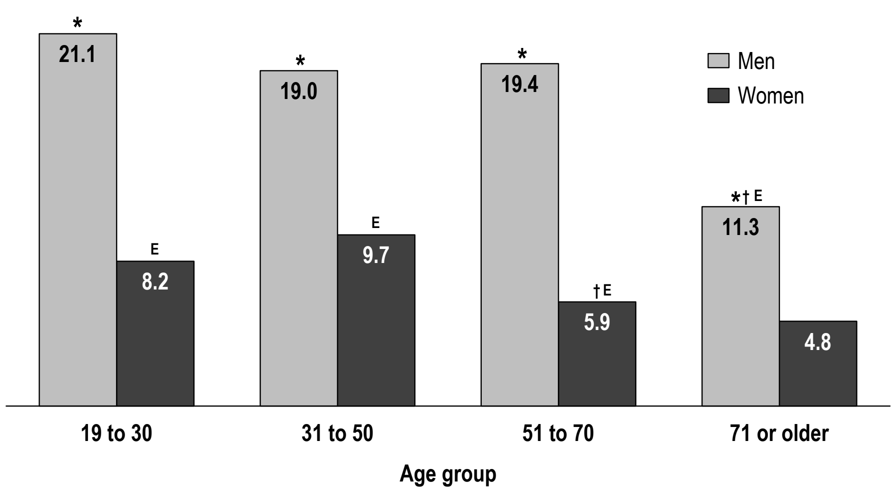
For men, beer was, the alcoholic beverage consumed by the largest proportions and in the greatest quantities.

Figure 1
Percentage with usual daily caffeine intake greater than 400 milligrams, by gender and age group, household population aged 19 or older, Canada excluding territories, 2004



* significantly different from estimate for women of same age (p< 0.05)
† significantly different from estimate for same sex in previous age group (p< 0.05)
E use with caution (coefficient of variation 16.6% to 33.3%)
Note: Excludes pregnant and breastfeeding women. Two outliers were excluded in 31-to-50 female category (intake greater than 5,000 mg). Estimated with the NCI method.[8] Probability of consuming and amount consumed were adjusted for weekend/weekday and smoking status.
Source: 2004 Canadian Community Health Survey – Nutrition.

Figure 2
Percentage with usual daily alcohol intake greater than 27.2 grams (two standard drinks), by gender and age group, household population aged 19 or older, Canada excluding territories, 2004



* significantly different from estimate for women of same age (p< 0.05)
† significantly different from estimate for same sex in preceding age group (p< 0.05)
E use with caution (coefficient of variation 16.6% to 33.3%)
Note: Excludes pregnant and breastfeeding women. Estimated with the NCI method.[8] Probability of consuming and amount consumed were adjusted for weekend/weekday and for frequency of drinking alcohol in past 12 months.
Source: 2004 Canadian Community Health Survey – Nutrition.

The people most likely to consume beer were men aged 19 to 50, 26% of whom reporting drinking beer the day before they were interviewed; at age 71 or older, the proportion was 12%. The quantity of beer that male consumers reported fell from an average of 1,159 grams (more than three bottles) at ages 19 to 30 to 567 grams (just over one bottle) at age 71 or older.

Much smaller proportions of women reported drinking beer. For example, 8% of women aged 19 to 30 drank beer the previous day, averaging 704 grams. At age 71 or older, 2% of women reported beer consumption.

For both sexes, the proportion consuming wine rose from around 5% at ages 19 to 30 to approximately 16% at ages 51 to 70. However, among wine drinkers, the average amount consumed was highest at ages 19 to 30 (402 grams for men; 291 grams for women). By age 71 or older, average consumption was 198 grams for men and 178 grams for women.

Fewer than 10% of adults reported drinking liquor or spirits the day before the interview. The average amount that they drank was around 160 grams at ages 19 to 30; by age 71 or older, the average was halved to about 75 grams.

Milk and fruit juice

Beverages help in meeting recommendations from Canada's Food Guide[3] for the consumption of dairy products (for example, milk) and vegetables and fruit (for example, fruit juice).

The proportion of adults who reported drinking milk tended to rise with age, from about half of 19- to 30-year-olds to around two-thirds of seniors aged 71 or older. Nonetheless, the average amount of milk they consumed dropped with advancing age. At ages 19 to 30, amounts averaged 408 grams for men and 328 grams for women; by age 71 or older, the averages were 260 and 198 grams, respectively. As a result, overall daily milk intake by people age 71 or older (consumers and non-

The data

This article is based on data from the 24-hour dietary recall component of the 2004 CCHS. Respondents were asked to list all foods and beverages consumed during the 24 hours before the day of their interview (midnight to midnight). Interviewers used the Automated Multi-pass Method,[9,10] with a five-step approach to help respondents remember what they had to eat and drink:

- a quick list (respondents reported all foods and beverages consumed in whatever order they wished);
- questions about specific food categories and frequently forgotten foods;
- questions about the time of consumption and type of meal (for example, lunch, dinner);
- questions seeking more detailed, precise descriptions of foods and beverages and quantities consumed; and
- a final review.

A subsample of the population responded to a second 24-hour recall a few days later to help assess day-to-day variations in food and beverage intake. The energy and nutrient content of the food and beverages was derived from Health Canada's Canadian Nutrient File 2001b, Supplement.[11]

A total of 35,107 people completed the initial 24-hour dietary recall, and a subsample of 10,786 completed the second recall. Response rates were 76.5% and 72.8%, respectively. Thirty-eight invalid or "null" recalls were excluded.

The first 24-hour recall for 20,159 adults aged 19 or older was used to estimate average beverage consumption. Usual intakes of caffeine and alcohol were based on both recalls, excluding 244 pregnant or breastfeeding women, and were estimated using the NCI method[8] in a two-part model: first, estimating the probability of consuming in a logistic regression model; second, estimating the amount consumed in a non-linear mix model. Both parts of the model were estimated simultaneously to account for the correlation between the probability of consuming and the amount consumed. As well, both parts of the caffeine model were adjusted by weekend/weekday and by *smoking status* (daily smoker, occasional smoker, non-smoker). Alcoholic beverages were listed in the 24-hour dietary recall of the CCHS, and in addition, a question in the general component of the survey asked about the frequency of alcohol consumption. Both parts of the alcohol model were adjusted by weekend/ weekday and by *frequency of drinking alcohol in the past 12 months* (never, less than once a month, once a month, 2 to 3 times a month, once a week, 2 to 3 times a week, 4 to 6 times a week, everyday).

The bootstrap method, which accounts for the complex survey design, was used to estimate standard errors, coefficients of variation, and confidence intervals.[12,13] The significance level was set at $p < 0.05$.

The beverage categories are based in groupings created by Health Canada's Bureau of Nutritional Sciences. Recipes and basic foods have separate categories. The categories were revised to eliminate double-counting. Beverages used in food recipes belonging to a non-beverage food category (milk in a cake recipe, for example) are excluded from the beverage categories.

The *water* category refers to municipal, bottled, well and distilled water consumed as such. It excludes water required to prepare another beverage (for instance, water in coffee is included in the coffee category).

The *milk* category includes all milk regardless of fat content, evaporated milk and milk added to tea or coffee. It also includes goat milk and infant formulas. Condensed milk and milk added to ready-to-eat or hot cooked cereals (on average, 45 grams a day) are excluded.

The *fruit juice* category refers to 100% pure juice, and includes the juice portion of alcoholic beverages and juice recipes (concentrate and water), whereas the *fruit drinks* category comprises beverages that contain less than 100% fruit juice.

The *tea* and *coffee* category excludes added items such as cream and sugar.

Alcoholic beverages are split into three categories: alcoholic *beer*, *wine* and *spirits and liquor*. In the last category, only the alcohol ingredient in a drink is included.

The methods used to gather information about food and beverage consumption are generally associated with some under-reporting. The 24-hour dietary recall is not exempt from this problem, even when the Automated Multiple-pass Method, which maximizes respondent recall, is used. Another report[14] has estimated calorie under-reporting at close to 10% for CCHS respondents aged 12 or older. Under-reporting of beverages strongly correlates with that of calories.

It is possible that some traces of a beverage category are found in another category in cases where it is impossible to separate certain ingredients in a mixture.

consumers) averaged 166 grams for men and 136 grams for women (Table 1).

For the total adult population, milk contributed approximately a half serving of dairy products to the daily diet. Adults' consumption of all dairy products, however, was relatively low, with more than two-thirds not exceeding two servings a day.[15]

The proportion of adults reporting fruit juice consumption varied little by age and sex—about one-third. However, similar to milk, quantities consumed dropped off sharply at older ages, from an average of 523 grams for men and 401 grams for women aged 19 to 30 to 221 grams for both sexes aged 71 or older.

For the total adult population (consumers and non-consumers), fruit juice consumption amounted to slightly more than one serving of vegetables and fruit at ages 19 to 30 and two-thirds of a serving at age 71 or older.

Around half of Canadian adults failed to meet the five daily servings of vegetables and fruit[15] recommended by the 1992 Food Guide, which was in effect when the 2004 CCHS was conducted (recommended levels were raised in 2007[3]). Even with the addition of vegetable juice, beverages generally made up less than one serving in this food group.

Energy intake from beverages

Depending on age, beverages can account for a substantial share of daily calories. Most of these calories come from regular soft drinks, alcohol, milk, fruit juice and fruit drinks.

Table 3
Percentage of daily calories derived from beverages, by gender and age group, household population aged 19 or older, Canada excluding territories, 2004

Age group	Men	Women
	%	
19 to 30	20.4*	17.9
31 to 50	16.0*†	14.3†
51 to 70	14.7*†	12.2†
71 or older	12.0†	11.3

* significantly different from estimate for women of same age ($p < 0.05$)
† significantly different from estimate for same sex in preceding age group ($p < 0.05$)
Note: Excludes pregnant and breastfeeding women.
Source: 2004 Canadian Community Health Survey – Nutrition.

At ages 19 to 30, beverages made up more than 20% of men's daily energy intake and about 18% of that of women (Table 3). The proportions fell with age, largely because of lower consumption of sweetened beverages (regular soft drinks and fruit drinks) and alcohol.

Comparison with the United States

According to a similar study of beverage consumption, based on 1999-2002 National Health and Nutrition Examination Survey data,[16] young adults in the United States drank slightly less fruit juice, milk products and coffee than did their Canadian counterparts (aged 20 to 39). However, in this age range, Americans consumed more than twice the amount of soft drinks, compared with Canadians.

In fact, the pattern of greater soft drink intake in the United States applied to all age groups. Tea consumption was the only other major difference between Canada and the US, with middle-aged Canadians (aged 40 to 59) drinking less, and older ones (aged 60 or older) drinking more. The American study did not examine water and alcoholic beverages.

Conclusion

What Canadian adults drank in 2004 depended on their age and sex. However, with one exception, the top three choices in 2004 were water, coffee and milk (though not necessarily in that order). The exception was men aged 19 to 30, among whom regular soft drinks ranked third in terms of the percentage reporting consumption.

How much of each beverage was consumed also depended on age and sex, with men typically drinking more than women, and amounts generally declining at older ages.

Some beverages tended to be consumed in greater quantities than others. Men and women of all ages who drank water reported drinking more of it than did consumers of any other beverage. Coffee, tea and diet soft drinks were also consumed in relatively large quantities.

These beverage consumption patterns were reflected in caffeine intake. At ages 31 to 70, around one in five adults exceeded Health Canada guidelines for caffeine consumption. ■

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Lead, mercury and cadmium levels in Canadians

by Suzy L. Wong and Ellen J.D. Lye

Abstract

The Canadian Health Measures Survey (CHMS), the most comprehensive direct health measures survey ever undertaken on a national scale in Canada, includes measurement of the heavy metals, lead, mercury and cadmium, which are toxic to humans at excessive levels. The geometric mean blood concentrations for lead, total mercury and cadmium were 1.37µg/dL, 0.76µg/L, and 0.35µg/L, respectively. Blood lead concentrations have fallen substantially since 1978, when national levels were last measured. Much of this decline may be attributed to the phase-out of leaded gasoline, lead-containing paints and lead solder in food cans since the 1970s. Fewer than 1% of Canadians now have blood lead concentrations above the Health Canada guidance value of 10µg/dL. Similarly, fewer than 1% of Canadian adults have total blood mercury concentrations above the Health Canada guidance value of 20µg/L for adults. CHMS data will be used to assess current population levels for a broad range of environmental chemicals, chronic diseases, nutritional status and infectious diseases; to provide a baseline for emerging trends, and to enable comparisons with other countries.

Keywords

biomonitoring, body burden, Canadian Health Measures Survey, environmental exposure, environmental pollution, heavy metals, public health

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The heavy metals lead, mercury and cadmium are widely dispersed in the environment, and at excessive levels, are toxic to humans.[1] Chronic exposure to these substances may also be hazardous. Although these metals occur naturally, exposure may be increased by human activities that release them into the air, soil, water and food, and by products that contain heavy metals.

This article presents preliminary data on blood levels of lead, total mercury, and cadmium in Canadians from the new Canadian Health Measures Survey (CHMS). These preliminary results are based on 8 collection sites from the CHMS. Results based on data from all 15 sites will be available in 2010.

The CHMS was launched by Statistics Canada in partnership with Health Canada and the Public Health Agency of Canada to collect data from approximately 5,000 Canadians aged 6 to 79 at 15 sites across Canada from March, 2007 to March, 2009. The CHMS entails an in-home general health interview and a subsequent visit to a mobile clinic where direct physical measures, including blood and urine samples, are taken.

The blood and urine samples are used to test for infectious diseases, nutritional status and cardiovascular disease risk factors, and also, for biomonitoring—that is, to measure levels of environmental chemicals. This biomonitoring component of the CHMS will help meet the need for nationally representative data on current population levels for a broad range of environmental chemicals, provide a baseline for emerging trends, and allow comparisons with other countries.

Lead

Sources of lead exposure include lead-based paint, lead plumbing, food grown in lead-contaminated soil, and toys, fuels or other products that contain lead or lead-based paints. Exposure to high lead levels can severely damage the brain and kidneys. Chronic exposure can result in decreased neurological performance. In pregnant women, exposure to high lead levels may cause

The data

Estimates are based on data from the Canadian Health Measures Survey (CHMS). During an in-home interview, demographic and socioeconomic data and information about lifestyle, medical history, current health status, the environment, and housing characteristics are collected. At a mobile clinic, physical measurements, such as blood pressure, height, weight and physical fitness are assessed. Blood and urine samples are taken to test for infectious diseases, nutritional status, cardiovascular disease risk factors, and levels of environmental chemicals, including heavy metals.

The CHMS covers the population aged 6 to 79 living in private households at the time of the interview. Residents of Indian Reserves or Crown lands, institutions and certain remote regions and full-time members of the Canadian Forces are excluded. Approximately 97% of Canadians are represented. Data are collected from 15 sites across Canada from March, 2007 through March, 2009. Ethics approval was obtained from Health Canada's Research Ethics Board. Informed written consent was obtained from respondents older than 14. For younger children, a parent or legal guardian provided written consent, and the children provided written assent. Participation is voluntary; participants can opt out of any part of the survey at any time. Additional information about the CHMS is available in print and online.[2-7]

The data in this article pertain to 2,678 participants from the first 8 data collection sites. Blood samples were drawn at the mobile clinic by a certified phlebotomist into 6 mL EDTA Becton Dickinson Vacutainer BD367863. Samples were stored in the mobile clinic freezer at -20°C, and once a week, were shipped on ice packs to the reference laboratory, the Centre de toxicologie du Québec (CTQ) of L'Institut national de santé publique du Québec (INSPQ). Blood samples were diluted in a basic solution containing octylphenol ethoxylate and ammonia, and analyzed for lead, total mercury and cadmium using inductively coupled plasma mass spectrometry (ICP-MS, DRC). INSPQ compiled, encrypted and electronically transmitted the results to Statistics Canada's Head Office. The laboratory is accredited under ISO 17025 and uses numerous external quality control programs, including the German External Quality Assurance Scheme (EQAS) and Lead and Multi-element Proficiency Testing (LAMP). Periodically, blind replicates and commercial controls are tested to monitor the precision of the assay.

For each heavy metal, the proportion above the limit of detection (LOD), proportion equal to or above the guidance value (where guidance values exist), geometric mean, selected percentiles, and 95% confidence intervals for the geometric mean and percentiles were calculated. The LOD is the level at which the blood concentration was so low that it could not be reliably or accurately determined by the laboratory test method. For lead, the LOD was 0.02µg/dL; for mercury, 0.10µg/L; and for cadmium, 0.04µg/L. To calculate the geometric mean and percentiles, blood concentrations less than the LOD were assigned a value equal to half the LOD.[8-10]

Geometric means were calculated by taking the log of each individual result, calculating the mean of those log values, and then taking the antilog of that mean. Compared with the arithmetic mean, the geometric mean is less influenced by high values, and therefore, provides a better estimate of central tendency for data that are distributed with a long tail at the upper end of the distribution—a common distribution when measuring environmental chemicals in blood.

The use of preliminary data limited the analyses that were possible for this article. Because data were available for only 8 of the 15 collection sites, the sample size was too small and/or the variability was too high to calculate statistically reliable estimates of the percentile distribution for mercury and selected percentiles for lead and cadmium, or to perform analyses by age groups, sex and smoking status. These analyses and others will be possible upon survey completion. For example, previous research suggests that heavy metal exposure is unlikely to be equal across the population; lead exposure varies by socioeconomic status,[11,12] and cadmium exposure[13-15] varies by smoking status. Future CHMS studies will be able to explore issues such as these.

Statistical analyses were based on weighted data. To account for survey design effects, standard errors, coefficients of variation and 95% confidence intervals were estimated using the bootstrap technique.[16-18]

miscarriage, and chronic exposure may affect the development of the foetus.[19]

Preliminary results from the CHMS show that the geometric mean blood lead concentration of Canadians is 1.37µg/dL (Table 1). Over 99% of Canadians aged 6 to 79 have measurable amounts of lead, that is, levels above the laboratory test method's limit of detection of 0.02µg/dL. However, having a measurable amount of lead in the blood does not necessarily mean that it will cause adverse health effects. Indeed, the current Health Canada blood lead guidance value for the general population is 10µg/dL.[20] A guidance value is the level above which follow-up actions may be considered to reduce exposure.

Fewer than 1% of the population have blood lead concentrations above the current Health Canada guidance value. (The coefficient of variation for this estimate was too high to reliably report a specific value.) This is a noticeable decline from 1978-1979 when results of the Canada Health Survey showed that 25% of Canadians aged 6 or older had blood lead concentrations above 10µg/dL.[21] Much of this decline may reflect the phase-out of leaded gasoline, lead-containing paints, and lead solder in food cans since the 1970s.[22]

The United States and Germany are among the few countries that have conducted nationally representative biomonitoring surveys that include testing for heavy metals. In the United States, the 2001-2002 National Health and Nutrition Examination Survey (NHANES) reported blood lead levels for the population aged 1 or older.[23] The 1998 German Environmental Survey (GerES III) and 2003-2006

Table 1
Geometric mean and selected percentiles of blood concentrations (in µg/dL) of lead, by age group, household population aged 6 to 79, 2007/2008

	Geometric mean	95% confidence interval from	95% confidence interval to	25th percentile	95% CI from	95% CI to	50th percentile	95% CI from	95% CI to	75th percentile	95% CI from	95% CI to	90th percentile	95% CI from	95% CI to	95th percentile	95% CI from	95% CI to
Total	1.37	1.19	1.58	0.88	0.74	1.02	1.32	1.14	1.50	2.06	1.73	2.39	3.13	2.60	3.65	3.87	3.14	4.61
6 to 19	0.88	0.77	0.99	0.62	0.55	0.69	0.85	0.74	0.97	1.14	0.89	1.39	1.61	1.29	1.92	2.05	1.57	2.54
20 to 79	1.50	1.32	1.72	1.00	0.88	1.12	1.44	1.27	1.60	2.23	1.87	2.58	3.35	2.84	3.87	4.11	3.18	5.03

Source: 2007/2008 Canadian Health Measures Survey.

Table 2
Geometric mean blood lead (µg/dL), total mercury (µg/L) and cadmium (µg/L) concentrations, by age group, Canadian Health Measures Survey and other selected surveys

	CHMS		NHANES (2001-2002)		GerES (1998 and 2003-2006)		INSPQ (2004)	
	Age group	Geometric mean	Age group	Geometric mean	Age group	Geometric mean	Age group	Geometric mean
Lead	6 to 19	0.88	6 to 11	1.25	6 to 8	1.73		
			12 to 19	0.94	9 to 11	1.56		
					12 to 14	1.45		
	20 to 79	1.50	20 or older	1.56	18 to 69	3.07	18 to 65	2.15
Total mercury	6 to 19	0.31^E^			6 to 8	0.23		
					9 to 11	0.22		
			16 to 49	0.83	12 to 14	0.26		
	20 to 79	0.91^E^	(females)		18 to 69	0.58	18 to 65	0.74
Cadmium	6 to 19	0.15	6 to 11	less than 0.3	6 to 8	less than 0.12		
			12 to 19	less than 0.3	9 to 11	less than 0.12		
					12 to 14	0.14		
	20 to 79	0.42	20 or older	less than 0.3	18 to 69	0.58	18 to 65	0.69

E use with caution (coefficient of variation 16.6% to 33.3%)
CHMS = 2007/2008 Canadian Health Measures Survey
NHANES = United States National Health and Nutrition Examination Survey
GerES = German Environmental Survey III and IV
INSPQ = Institut national de santé publique du Québec

German Environmental Survey for Children (GerES IV) reported blood lead levels for adults aged 18 to 69 and children aged 6 to 14, respectively.[13,24] Blood lead levels have also been reported from a survey of the non-occupationally exposed general population aged 18 to 65 in the Quebec City Region.[14] A comparison of the geometric mean blood lead concentrations showed that Canadians overall have similar or slightly lower blood lead levels, compared with these populations (Table 2).

Total mercury

There are three chemical forms of mercury: elemental, inorganic, and organic, notably, methylmercury. Exposure of the general population is primarily to methylmercury and occurs through the consumption of fish and seafood.[25] To a much lesser extent, the general population is exposed to inorganic mercury through dental amalgams.[25] Previous studies have shown that inorganic mercury comprises 14% to 26% of total blood mercury.[26-28] Thus, a measurement of total blood mercury consists primarily of methylmercury.

Table 3
Geometric mean blood concentrations (in µg/L) of total mercury, by age group, household population aged 6 to 79, 2007/2008

Age group	Geometric mean	95% confidence interval from	95% confidence interval to
Total	0.76^E^	0.51	1.13
6 to 19	0.31^E^	0.23	0.43
20 to 79	0.91^E^	0.63	1.32

E use with caution (coefficient of variation 16.6% to 33.3%)
Note: The coefficient of variation was too high to reliably report the percentiles.
Source: 2007/2008 Canadian Health Measures Survey.

Table 4
Geometric mean and selected percentiles of blood concentrations (in µg/L) of cadmium, by age group, household population aged 6 to 79, 2007/2008

Age group	Geometric mean	95% confidence interval from	95% confidence interval to	25th percentile	95% confidence interval from	95% confidence interval to	50th percentile	95% confidence interval from	95% confidence interval to	75th percentile	95% confidence interval from	95% confidence interval to
Total	0.35	0.31	0.39	0.15	0.12	0.18	0.28	0.25	0.31	0.62	0.49	0.75
6 to 19	0.15	0.12	0.18	0.09	0.07	0.10	0.13	0.11	0.15	0.21	0.18	0.24
20 to 79	0.42	0.37	0.48	0.19	0.17	0.21	0.34	0.31	0.37	0.79	0.55	1.02

Note: The coefficient of variation for additional percentiles was too high to reliably report the corresponding estimates.
Source: 2007/2008 Canadian Health Measures Survey.

Chronic exposure to methylmercury may cause numbness and tingling in the extremities, blurred vision, deafness, lack of muscle coordination and intellectual impairment, as well as adverse effects on the cardiovascular, gastrointestinal and reproductive systems. Prenatal exposure may interfere with foetal development of the central nervous system and cause neurological and developmental delays. Women who are exposed to methylmercury and breastfeed may also expose the child through the milk.[29]

Preliminary CHMS results show that the geometric mean blood mercury level of Canadians aged 6 to 79 is 0.76µg/L (Table 3), with approximately 90% having concentrations above the limit of detection of 0.10µg/L. (Because the coefficient of variation for this estimate was between 16.6% and 33.3%, it should be interpreted with caution.) However, fewer than 1% of Canadians aged 20 to 79 have total mercury concentrations above the current Health Canada blood guidance value of 20 µg/L[30] established for the general adult population. (The coefficient of variation for this estimate was too high to reliably report a specific value.)

A comparison of the geometric mean blood mercury concentrations shows that Canadians overall have similar or slightly higher levels than those of the general population in Germany,[13,24] females aged 16 to 49 in the United States,[23] and a non-occupationally exposed population in the Quebec City region[14] (Table 2).

Cadmium

Sources of exposure to cadmium include diet, drinking water and occupational exposure. For the non-occupationally exposed population, cigarette smoking is considered to be a major source of exposure.[31,32]

Chronic exposure to cadmium may cause kidney damage, bone mineral density loss and hypertension.[32,33] Acute and chronic inhalation of cadmium can cause potentially fatal pulmonary dysfunction.[32] In addition, cadmium has been classified as carcinogenic by the International Agency for Research on Cancer, with exposure being primarily associated with lung cancer.[34]

According to preliminary CHMS results, the geometric mean blood cadmium of Canadians aged 6 to 79 is 0.35µg/L, with about 98% having levels above the limit of detection of 0.04µg/L (Table 4). No Canadian blood cadmium guidance value has been established for the general population. Occupational exposure guidance values exist, but they are not applicable to the population overall. Previous research has shown that cigarette smoking can raise blood cadmium to levels that are at least 2.5 to 4 times higher than in non-smokers,[13-15] but because of the small sample size, such associations could not be examined in this article.

A comparison of the geometric mean blood cadmium concentrations shows that Canadians' blood cadmium levels are similar to those of the general population of the United States[23] and Germany,[13,24] and a non-occupationally exposed population in the Quebec City region[14] (Table 2).

Summary

These preliminary findings from the Canadian Health Measures Survey provide national population estimates for blood lead levels, which have not been measured since 1978, as well as the first national population estimates for total mercury and cadmium levels. While most Canadians have measurable amounts of these heavy metals in their blood, this does not necessarily mean that they experience adverse health effects. Indeed, fewer than 1% of Canadians aged 6 to 79 have blood lead levels above the current Health Canada general population guidance value of 10µg/dL, and fewer than 1% of those aged 20 to 79 have total blood mercury levels above the Health Canada guidance value of 20µg/L for the general adult population. Canadians' levels of lead, total mercury and cadmium are similar to those of people in the United States[23] and Germany.[13,24] ■

Further information about the CHMS can be found at:

- Statistics Canada: www.statcan.ca/chms

Further information about biomonitoring, and specifically, lead, mercury and cadmium, their health effects, and ways to minimize exposure can be found at:

- Health Canada: www.hc-sc.gc.ca
- Chemical Substances in Canada: www.chemicalsubstances-chimiques.gc.ca.

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Under-reporting of energy intake in the Canadian Community Health Survey

by Didier Garriguet

Abstract

Background
Under-reporting of food consumption is a recurrent challenge for nutrition surveys. Past research suggests that under-reporting tends to be most pronounced among overweight and obese people.

Data and methods
Data from 16,190 respondents to the 2004 Canadian Community Health Survey (CCHS 2.2)—Nutrition were used to estimate under-reporting of food intake for the population aged 12 or older in the 10 provinces. Multiple linear regression models were used to assess the impact of different characteristics on under-reporting.

Results
Average under-reporting of energy intake was estimated at 10%. Under-reporting was greater among people who were overweight or obese, those who were physically active, adults compared with teenagers, and women compared with men.

Interpretation
Under-reporting of energy intake is not random and varies by key health determinants. Awareness of the characteristics associated with under-reporting is important for users of nutrition data from the CCHS 2.2.

Keywords
caloric intake, diet, food habits, energy expenditure, energy metabolism, nutrition surveys, twenty-four hour recall

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Data collection is particularly challenging in nutrition surveys. The majority of studies based on data from such surveys have revealed a problem with under-reporting[1-6]; that is, respondents tend to report that they ate and drank less than they actually did.

Body mass index, in particular, has been linked to under-reporting of food consumption (energy intake).[1,3-6] And while there are no clear conclusions with respect to age and sex, under-reporting tends to be more common among women and older people.[2-4,6] Health, socio-economic and psychological characteristics have also been linked to under-reporting.[1,3,5,6]

In 2004, Statistics Canada conducted the Canadian Community Health Survey (CCHS) — Nutrition, the first national survey of the eating habits of Canadians since the early 1970s. As has been the case for similar surveys, the 2004 CCHS was susceptible to under-reporting.

This article quantifies under-reporting of energy intake in the CCHS at the group level. It also compares modelled total energy expenditure of CCHS respondents to their reported energy intake to determine if groups identified in the literature as being more likely to under-report are the same for the Canadian population. This information is valuable to researchers using the CCHS, who should be aware of its potential limitations.

Methodology

Data source

The 2004 CCHS was designed to collect information about the food and nutrient intake of the household population at the national and provincial levels. It excludes members of the regular Canadian Forces, residents of the three territories, people on Indian reserves, in institutions and in some remote areas, as well as all residents (military and civilian) of Canadian Forces bases. Detailed descriptions of the design, sample and interview procedures are available in a published report.[7]

A total of 35,107 people completed an initial 24-hour dietary recall; a subsample of 10,786 completed a second recall three to ten days later. Response rates were 76.5% and 72.8%, respectively. Only the first 24-hour recall was used for this analysis.

All CCHS respondents aged 2 or older were supposed to be measured and weighed, but for various reasons, height and weight data were not collected for around 40% of them. To adjust for this non-response, another survey weight was created, based on respondent classes with similar demographic and socio-economic characteristics. Because of the bias that has been observed between the two types of data,[8,9] measured height and weight are preferable to self-reported height and weight. Therefore, respondents with measured height and weight data (with the appropriate survey weight) were used for this analysis.

This study was restricted to respondents aged 12 or older who answered the leisure-time physical activity questions. Women who were pregnant or breastfeeding, people of very low weight (body mass index less than 18.5kg/m^2), and respondents with no or invalid dietary intakes were excluded. A total of 16,190 respondents were included in the study.

The CCHS used a 24-hour dietary recall to estimate Canadians' energy intake. To help respondents remember what and how much they ate and drank the previous day, a five-step method, known as the Automated Multiple Pass Method (AMPM),[10,11] was employed. The five steps are:

- A quick list (participants listed all the beverages and food consumed);
- A series of questions on specific categories of foods and certain frequently forgotten foods;
- Questions about the time and occasion of consumption;
- A series of questions to collect more detailed information on the foods and beverages, and quantities; and
- A final review.

The energy and nutrient composition of the food reported during this recall came from Health Canada's Canadian Nutrient File (2001b Supplement).[12]

Total energy expenditure

For people who maintain their weight, usual energy intake (calories consumed) equals energy expenditure (calories expended). If intake exceeds expenditure, they gain weight; if intake is less than expenditure, they lose weight. The same is true for a population. In a population with a stable body mass, energy intake and expenditure are virtually equal. A comparison of the average energy intake of a surveyed population with its average energy expenditure yields an estimate of the accuracy of the estimate of energy intake.

With data from the 2004 CCHS, it is possible to estimate respondents' energy intake, but not their energy expenditure. The most widely accepted method of estimating energy expenditure is a doubly labelled water study. This involves administering two forms of isotopes of water to an individual and measuring the rate of disappearance in the urine or in the blood over a given period. These rates are then used to calculate the rate of carbon dioxide (CO_2) production, which, combined with the individual's diet, makes it possible to calculate energy expenditure.[13]

With a number of doubly labelled water studies, the Institute of Medicine (IOM) modelled total energy expenditure (TEE) or estimated energy requirements (EER), based on age, sex, weight, height and physical activity level (PAL) (Table 1). These equations were used to estimate the energy requirements of CCHS respondents.

Predicting energy requirements

With the IOM equations, energy requirements can be predicted if age, sex, height, weight, and physical activity level are known. While age, sex, height and weight are readily available in the CCHS, the physical activity data pertain only to leisure time; information was not collected about activity related to work or transportation. Moreover, daily energy expenditure in the CCHS was measured in Metabolic Equivalents (MET), expressed as kilocalories per kilogram per day, whereas the IOM measures energy expenditure by Physical Activity Level (PAL). MET describes the intensity of an activity compared with resting metabolic rate (RMR); PAL represents the ratio between total energy expenditure (TEE) and basal energy expenditure (BEE).

Using the methodology of the IOM,[14] each physical activity reported in MET values can also be reported in change in physical activity level (ΔPAL), based on the increase in TEE arising from the practice of that activity.

The following formulas were used to determine ΔPAL using MET values for each physical activity that CCHS respondents reported having participated in during the previous three months:

$$\Delta PAL = (MET - 1) * N_{times} * Minutes * 1.34 / 1{,}440 \quad \text{(for men)}$$

and

$$\Delta PAL = (MET - 1) * N_{times} * Minutes * 1.42 / 1{,}440 \quad \text{(for women)}$$

where N_{times} represents the number of times an activity was practiced, and Minutes represents the average duration (13, 23, 45 or 60 minutes) of the activity, based on whether it was practiced for less than 15 minutes, between 15 and 30 minutes, between 30 and 60 minutes, or more than 60 minutes.

To assess the full impact of an activity on total energy expenditure (TEE), additional energy spent in relation to the activity must be taken into account. First, 15% of the energy expended from a physical activity must be added to energy expenditure to account for excess post-exercise oxygen consumption (EPOC).

Second, the increased energy expenditure associated with the physical activity will require an increase in energy intake (if the individual is to maintain his or her weight). Consequently, the thermic effect of food (TEF), which dissipates an estimated 10% of the energy consumed, must also be taken into account.

A final adjustment accounts for the use of basal energy expenditure (BEE) instead of resting metabolic rate (RMR). A MET of 1.0 extrapolated to 24 hours

Table 1
Estimated energy requirements (EER) based on Institute of Medicine (IOM) equations, by body mass index, age and sex

Body mass index (BMI), age and sex	Institute of Medicine equation for estimated energy requirement
BMI between 18.5 kg/m² and 25 kg/m²	
Ages 9 to 18	
Male	EER = 113.5 - 61.9*age (years) + PAL * (26.7 * weight (kg) + 903 * height (m)), where PAL = 1 if sedentary, 1.13 if low active, 1.26 if active, and 1.42 if very active.
Female	EER = 160.3 - 30.8*age (years) + PAL * (10 * weight (kg) + 934 * height (m)), where PAL = 1 if sedentary, 1.16 if low active, 1.31 if active, and 1.56 if very active.
Ages 19 or older	
Male	EER = 661.8 - 9.53*age (years) + PAL*(15.91* weight (kg) + 539.6* height (m)), where PAL = 1 if sedentary, 1.11 if low active, 1.25 if active, and 1.48 if very active.
Female	EER = 354.1 - 6.91*age (years) + PAL*(9.36* weight (kg) + 726* height (m)), where PAL = 1 if sedentary, 1.12 if low active, 1.27 if active, and 1.45 if very active.
BMI more than 25 kg/m²	
Ages 9 to 18	
Male	EER = -114.1-50.9*age (years) + PAL * (19.5*weight (kg) + 1161.4*height (m)), where PAL = 1 if sedentary, 1.12 if low active, 1.24 if active, and 1.45 if very active.
Female	EER = 389.2 - 41.2*age (years) + PAL * (15 * weight (kg) + 701.6 * height (m)), where PAL = 1 if sedentary, 1.18 if low active, 1.35 if active, and 1.60 if very active.
Ages 19 or older	
Male	EER = 1085.6 - 10.08*age (years) + PAL*(13.7* weight (kg) + 416* height (m)), where PAL = 1 if sedentary, 1.12 if low active, 1.29 if active and 1.59 if very active.
Female	EER = 447.6 - 7.95*age (years) + PAL*(11.4* weight (kg) + 619* height (m)), where PAL = 1 if sedentary, 1.16 if low active, 1.27 if active and 1.44 if very active.

Note: PAL is physical activity level.
Source: Institute of Medicine. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids. Washington, DC: National Academy Press, 2005.[14]

will be 5% higher than the BEE for a reference 70 kg man and 10% higher for a 57 kg reference woman. These adjustments are represented by the factors of 1.34 for men (1.15 (EPOC) ÷ 0.9 (TEF) ÷ 0.95) and 1.42 for women (1.15 (EPOC) ÷ 0.9 (TEF) ÷ 0.91).

Since MET is a daily measurement, a factor of 1,440 converts this increase in energy expenditure into a measure per minute. For example, swimming has a MET value of 3.0 kcal/kg/hour. For a man, swimming an hour a day over three months amounts to an increase in physical activity of (3.0 MET - 1) * 90 days * 60 minutes * 1.34 / 1,440 = 10.05, or a daily increase of 0.112, representing an increase in total energy expenditure of 189 kcal a day.

Once all individual leisure-time physical activities have been expressed in ΔPAL for three months, values are summed and divided by 90 days to represent the daily increase in energy expenditure resulting from physical activity.

According to the IOM methodology, a person involved in only sedentary pursuits will have a physical activity level of 1.39. The final PAL for one person is obtained by adding the sum of ΔPAL to the base PAL of 1.39. The IOM divides physical activity levels into four categories: sedentary (PAL 1.0 to less than 1.4), low active (PAL 1.4 to less than 1.6), active (PAL 1.6 to less than 1.9), and very active (PAL 1.9 to less than 2.5).

Respondents to the 2004 CCHS were placed in three categories based on their energy expenditure calculated in MET: inactive, moderately active, and active. Table 2 compares the PAL and MET classifications of respondents for whom the information needed to predict energy requirements was available.

With these variables and the IOM equations described above, it is possible to predict the energy requirements of these CCHS respondents.

Measuring under-reporting of energy intake

Two methods can be used to measure the extent to which energy intake (that is, food consumption) is under-reported. The first method, which is employed in this study, involves a macro-estimation that uses only the ratio of measured energy intake to energy requirements predicted with the IOM equations: a ratio less than 1 indicates under-reporting; a ratio greater than 1, over-reporting. (The second method involves classifying respondents according to whether their food intake is deemed to be under-reported, over-reported or plausible. This method is presented in a separate paper.[15])

To assess the effect of energy under-reporting on a group average, the ratio of the average energy intake of a group is divided by the average energy expenditure predicted for that group. To assess the effect of energy under-

Table 2
Physical Activity Level (PAL) versus Metabolic Equivalents (MET), household population aged 12 or older, Canada excluding territories, 2004

Physical activity category (in PAL)	Physical activity category (in MET)		
	Inactive	Moderately active	Active
Sedentary	2,637	0	0
Low active	5,537	3,975	2,460
Active	0	0	1,412
Very active	0	0	169

Source: 2004 Canadian Community Health Survey – Nutrition.

reporting while simultaneously taking multiple groups into account, individual ratios of energy intake to predicted energy expenditure are modelled in a multiple linear regression.

The covariates that were included in the multiple linear regressions were chosen based on the literature and on factors known to influence the quantity or quality of food consumed. These covariates were divided into three categories: risk factors (body mass index, leisure-time physical activity, alcohol consumption, fruit and vegetable consumption, and smoking status), health status (self-reported health and the presence of chronic conditions), and socio-demographic characteristics (sex, age, household education and income, employment status, immigrant status, Aboriginal status, and province of residence).

The risk factors were included because poor food choices are associated with under-reporting energy intake; specifically, people tend to under-report unhealthy items and over-report healthy items. The variables that were chosen generally reflect healthy lifestyles or the quality of food choices.

Since poor health can affect appetite, the two health status variables were included to control for factors that might affect the quantity of food consumed.

The socio-demographic variables were included because the literature has shown that some of them are related to under-reporting. As well, because population subgroups are often defined by these variables (for example, seniors, Aboriginal people, immigrants), it is important to know how under-reporting is associated with these characteristics. Also, some of these characteristics (for example, low household income) are related to poorer quality diets.

The bootstrap method, which takes account of the complex survey design,[16-18] of the CCHS was used to estimate confidence intervals of the ratios and regression coefficients. The significance level was set at $p < 0.05$.

Definitions

Body mass index (BMI) is calculated by dividing weight in kilograms by height in metres squared. In this analysis, the BMI categories for adults were defined according to Health Canada's guidelines.[19] People whose BMI was between 18.5 kg/m^2 and 24.99 kg/m^2 were normal weight; between 25 kg/m^2 and 29.99 kg/m^2 , overweight; and more than 30 kg/m^2 , obese. For adolescents aged 12 to 17, the categories defined by Cole et al.[20] were used.

Leisure-time physical activity level refers to the four PAL categories: sedentary, low active, active, and very active.

Alcohol consumption refers to the 12 months before the CCHS interview.

Fruit and vegetable consumption is based on the reported usual frequency of consumption, not the 24-hour recall. It represents the number of times per day respondents consumed fruit and vegetables, not the amount of food consumed.

Smokers are those who smoke daily and occasionally.

The socio-demographic variables are: *sex* and *age* for adults, based on the IOM dietary reference groups; *highest level of education in the household* (less than secondary graduation, secondary graduation, some postsecondary, postsecondary graduation); household income from all sources, accounting for household size (low, low/average, average, average/high, and high); *employment status* the week before the interview; and *immigrant* and *Aboriginal* status.

The variables related to health status are *self-reported health* (excellent, very good, good, fair and poor) and the presence of at least one *chronic condition*.

Results

Overall, the ratio of CCHS respondents' reported energy intake (EI) to their energy expenditure requirements (EER) predicted by the IOM equations was 0.904 (Table 3). In other words, Canadians aged 12 or older reported that they consumed about 10% fewer calories than they actually required, given their height, weight and level of physical activity. Ratios tended to be lower for females, although the difference was significantly different from men only among 19- to 30-year-olds. As well, the ratios decreased with age, indicating that under-reporting became greater at successively older ages.

With a regression model, the influence of several variables can be examined simultaneously. Separate models were constructed for adolescents (12 to 17) and for adults (18 or older). The regression coefficients represent the change in the ratio associated with the change in a characteristic in relation to the "reference person." For adults,

Table 3
Ratio of energy intake estimate to predicted energy expenditure requirements, by age group and sex, household population aged 12 or older, Canada excluding territories, 2004

Age group and sex	Ratio	95% confidence interval from	95% confidence interval to
Total	0.904	0.890	0.917
12 or 13			
Male	1.009	0.950	1.067
Female	0.992	0.934	1.050
14 to 18			
Male	0.977	0.939	1.016
Female	0.949	0.917	0.981
19 to 30			
Male	0.962*	0.921	1.003
Female	0.866†	0.828	0.904
31 to 50			
Male	0.920	0.877	0.962
Female	0.876	0.842	0.910
51 to 70			
Male	0.877	0.846	0.907
Female	0.856	0.829	0.884
71 or older			
Male	0.836	0.796	0.877
Female	0.887	0.853	0.921

* significantly different from estimate for females in same age group ($p < 0.05$)
† significantly different from estimate for previous age group of same sex ($p < 0.05$)
Source: 2004 Canadian Community Health Survey – Nutrition.

Table 4
Linear regression coefficients of ratio of reported energy intake in relation to predicted energy expenditure requirements, by sex, household population aged 18 or older, Canada excluding territories, 2004

	Men			Women		
		95% confidence interval			95% confidence interval	
Characteristics	beta coefficient	from	to	beta coefficient	from	to
Intercept	1.065	0.958	1.171	0.909	0.829	0.990
Body mass index						
Overweight (25 kg/m^2≤ BMI<30 kg/m^2)	-0.119*	-0.171	-0.068	-0.138*	-0.177	-0.098
Obese (≥30 kg/m^2)	-0.205*	-0.258	-0.152	-0.191*	-0.231	-0.150
Physical activity						
Sedentary	0.092*	0.015	0.169	0.123*	0.080	0.165
Active	-0.077	-0.161	0.007	-0.080	-0.173	0.013
Very active	-0.152	-0.312	0.009	-0.395*	-0.752	-0.038
Consumed alcohol in previous year	0.043	-0.023	0.108	0.040	-0.003	0.084
Has at least one chronic condition	-0.046	-0.096	0.004	0.026	-0.014	0.067
Highest level of education in household						
Less than secondary graduation	0.033	-0.044	0.110	-0.071*	-0.121	-0.022
Secondary graduation	-0.041	-0.102	0.021	-0.082*	-0.125	-0.038
Some postsecondary	-0.017	-0.082	0.048	-0.074*	-0.130	-0.017
Daily consumption of fruit and vegetables						
Fewer than 5 servings	-0.071*	-0.118	-0.024	-0.001	-0.038	0.037
More than 10 servings	-0.012	-0.207	0.182	-0.009	-0.201	0.182
Self-reported health						
Very good	-0.011	-0.066	0.043	-0.026	-0.084	0.032
Good	-0.004	-0.066	0.058	-0.070*	-0.127	-0.013
Fair	-0.002	-0.088	0.085	-0.064	-0.137	0.009
Poor	0.013	-0.120	0.146	-0.091	-0.212	0.031
Household income						
Low	-0.071	-0.174	0.032	-0.025	-0.110	0.061
Low/Average	0.016	-0.116	0.149	-0.031	-0.088	0.025
Average	-0.041	-0.108	0.026	-0.016	-0.066	0.035
Average/High	0.005	-0.043	0.053	0.003	-0.042	0.047
Did not work in week before interview	-0.024	-0.071	0.023	0.045*	0.004	0.086
Immigrant	-0.045	-0.100	0.010	0.013	-0.033	0.059
Smoker	0.052*	0.001	0.103	-0.045	-0.081	-0.009
Aboriginal person	0.054	-0.051	0.158	0.056	-0.025	0.137
Province						
Newfoundland and Labrador	0.031	-0.047	0.109	-0.026	-0.089	0.036
Prince Edward Island	0.003	-0.077	0.084	-0.012	-0.063	0.040
Nova Scotia	0.029	-0.045	0.103	0.030	-0.030	0.090
New Brunswick	0.050	-0.034	0.134	-0.053*	-0.104	-0.001
Quebec	0.078*	0.013	0.142	0.117*	0.066	0.168
Manitoba	-0.014	-0.074	0.046	0.023	-0.030	0.075
Saskatchewan	0.026	-0.059	0.112	0.014	-0.044	0.073
Alberta	-0.004	-0.069	0.062	-0.001	-0.053	0.051
British Columbia	0.116*	0.044	0.189	0.063*	0.010	0.117
Age group						
31 to 50	-0.041	-0.099	0.017	0.022	-0.027	0.071
51 to 70	-0.048	-0.109	0.014	0.002	-0.050	0.054
71 or older	-0.092*	-0.169	-0.016	0.057*	0.000	0.113

* coefficient significantly different from 0 ($p < 0.05$)
Note: The reference person has a normal BMI, is low active, lives in a household where at least one member is a postsecondar graduate, has 5 to 10 servings of fruit and vegetables each day, is in excellent health, lives in a household in the highest income category, worked the week before the interview, is not an immigrant or an Aboriginal person, does not smoke, lives in Ontario, and is aged 18 to 30.
Source: 2004 Canadian Community Health Survey – Nutrition.

Table 5
Linear regression coefficients of ratio of energy intake in relation to predicted energy expenditure requirements, by sex, household population aged 12 to 17, Canada excluding territories, 2004

	Boys			Girls		
		95% confidence interval			95% confidence interval	
Characteristics	beta coefficient	from	to	beta coefficient	from	to
Intercept	1.167	1.065	1.268	1.120	1.037	1.202
Body mass index						
Overweight (25 kg/m^2 ≤ BMI<30 kg/m^2)	-0.108*	-0.181	-0.035	-0.277*	-0.341	-0.212
Obese (≥30 kg/m^2)	-0.309*	-0.384	-0.234	-0.364*	-0.462	-0.267
Physical activity						
Sedentary	0.168	-0.041	0.377	0.288*	0.145	0.431
Active	-0.127*	-0.190	-0.064	-0.146*	-0.211	-0.081
Very active	-0.109	-0.244	0.027	-0.208*	-0.409	-0.007
Consumed alcohol in previous year	-0.082*	-0.145	-0.020	-0.039	-0.099	0.020
Has at least one chronic condition	0.033	-0.037	0.104	0.033	-0.040	0.106
Highest level of education in household						
Less than secondary graduation	-0.062	-0.257	0.133	-0.013	-0.118	0.091
Secondary graduation	-0.094*	-0.170	-0.017	-0.029	-0.114	0.057
Some postsecondary	-0.155*	-0.241	-0.068	-0.029	-0.119	0.061
Daily consumption of fruit and vegetables						
Fewer than 5 servings	-0.079*	-0.152	-0.006	-0.058*	-0.115	-0.001
More than 10 servings	0.053	-0.216	0.322	0.097	-0.184	0.378
Self-reported health						
Very good	-0.043	-0.110	0.023	-0.037	-0.116	0.043
Good	-0.057	-0.152	0.039	-0.047	-0.133	0.039
Fair	-0.108	-0.243	0.027	-0.052	-0.184	0.080
Poor	-0.289*	-0.522	-0.056	-0.025	-0.367	0.318
Household income						
Low	-0.196	-0.406	0.014	0.094	-0.133	0.321
Low/Average	0.021	-0.156	0.198	0.064	-0.045	0.174
Average	-0.002	-0.095	0.091	0.050	-0.051	0.152
Average/High	-0.029	-0.101	0.043	0.086*	0.004	0.168
Immigrant	0.080	-0.049	0.209	-0.114	-0.256	0.028
Smoker	0.109*	0.004	0.213	-0.006	-0.092	0.080
Aboriginal person	0.088	-0.194	0.371	0.041	-0.134	0.217
Province						
Newfoundland and Labrador	0.027	-0.090	0.144	-0.038	-0.151	0.074
Prince Edward Island	0.033	-0.087	0.152	-0.008	-0.150	0.133
Nova Scotia	-0.031	-0.172	0.111	-0.033	-0.156	0.091
New Brunswick	0.103	-0.043	0.249	0.015	-0.064	0.095
Quebec	0.183*	0.092	0.274	0.049	-0.048	0.146
Manitoba	0.088	-0.006	0.182	0.015	-0.077	0.107
Saskatchewan	0.140*	0.029	0.251	0.052	-0.067	0.170
Alberta	0.017	-0.077	0.112	-0.085*	-0.169	-0.001
British Columbia	0.028	-0.073	0.128	-0.055	-0.132	0.023

* coefficient significantly different from 0 ($p < 0.05$)

Note: The reference person has a normal BMI, is low active, lives in a household where at least one member is a postsecondary graduate, has 5 to 10 servings of fruit and vegetables each day, is in excellent health, lives in a household in the highest income category, is not an immigrant or an Aboriginal person, does not smoke, and lives in Ontario.

Source: 2004 Canadian Community Health Survey – Nutrition.

the reference person had the following characteristics: BMI in the normal range; low active; lived in Ontario in a household in the highest income category where at least one member was a postsecondary graduate; consumed 5 to 10 servings of fruit and vegetables a day; excellent health; worked the week before the interview; neither an immigrant nor an Aboriginal person; non-smoker; aged 18 to 30. The reference person for adolescents had the same characteristics, except for age and employment the week before the interview.

Regardless of age group and sex, BMI category had a significant and consistent impact on the ratio of energy intake to predicted energy expenditure requirements (Tables 4 and 5). People who were overweight or obese under-reported their energy intake, compared with the reference person (of normal weight).

Leisure-time physical activity was also significantly related to reporting energy intake, but the direction of the estimate depended on the level of activity. Among those who were sedentary, adults of both sexes and girls aged 12 to 17 actually overestimated how much they ate. By contrast, active adolescents of both sexes and very active adult women and adolescent girls under-reported.

Low fruit and vegetable consumption (fewer than 5 servings a day) was associated with under-reporting for all groups except adult women. Similarly, male adolescents who had consumed alcohol in the past year under-reported their energy intake. By contrast, men and male adolescents who were smokers tended to overestimate the amount they consumed.

Under-reporting of energy intake was greater among women who were in good health and among male adolescents who were in poor health. Having a chronic condition was not linked to energy reporting.

While household income had almost no association with the reporting of energy intake, differences emerged by level of education in the household. Among women, all levels of household education below postsecondary graduation were associated with under-reporting. Under-reporting was also statistically significant among adolescent boys in households where the highest level of education was secondary graduation or some postsecondary.

Immigrant and Aboriginal status did not influence the reporting of energy intake. Nor was age group among adults a significant factor—the major difference was between adolescents and adults.

Finally, adults in Quebec and British Columbia over-reported how much they consumed, while women in New Brunswick under-reported. Among adolescents, males in Quebec and Saskatchewan over-reported their consumption, and females in Alberta under-reported.

Discussion

Under-reporting in the nutrition component of the 2004 CCHS amounted to about 10% of total energy intake for the population aged 12 or older. However, the extent of under-reporting varied with a number of factors, notably, body mass index, physical activity, lifestyle factors, and level of household education.

The results of the present analysis confirm what has been observed in other research. A review article that examined 25 studies[6] found BMI categories to be closely linked to energy under-reporting. Other studies have also generally shown that women and older individuals were more likely to under-report. In the present study, too, women tended to under-report energy intake more than men did, but age differences were greater between adolescents and adults than between adult age groups.

Physical activity was linked to energy reporting in this study. A number of earlier analyses did not take physical activity into account when calculating energy requirements.

The CCHS data show that smoking was associated with over-reporting energy intake among males of all ages. This suggests a link between smoking and a poorer quality diet, which has frequently been found in other research.[21-25]

The results for socio-demographic factors have been less consistent from study to study, although lower levels of education have been associated with under-reporting energy intake. Results from the CCHS show that level of household education was significantly linked to under-reporting among adult women and male adolescents.

Limitations

The major limitation of the present study is that the measure of under-reporting of energy intake is highly dependent on the quality of the estimate of energy expenditure. However, information about energy expenditure from the 2004 CCHS is incomplete, as the survey collected data only about leisure-time physical activity.

This analysis used the base 1.39 physical activity level for all respondents, but other assumptions could have been made. For example, if it had been assumed that all respondents were "low active" (the most frequently reported physical activity category), the EI:EER ratio for the population aged 12 or older would be 0.895. Even so, this would not change the relationship between under-reporting and the characteristics shown to be associated with it, especially overweight and obesity.

Assuming a "sedentary" physical activity level for all respondents would yield an estimated EI:EER ratio of 1.003 for the population aged 12 or older. But a substantial number of people would have higher energy requirements based on their leisure-time physical activity. And contrary to the assumption of low physical activity for all respondents, where misclassification can occur in both directions, assuming sedentary physical activity can lead to misclassification in only one direction, and the true EI:EER ratio would necessarily be below 1.

Another option would have been to use the ratio between energy intake and either basal metabolic rate (BMR) or basal energy expenditure (BEE). These ratios would represent an average physical activity level in the population. To estimate under-reporting, it would still be necessary to estimate physical activity. However, instead of using categories, a continuous variable would have to be used, which would be more sensitive to misreporting than a categorical variable.

Although the IOM equations are the best currently available, the database is not a representative sample of either the Canadian or American population. As well, the model used to derive the EER leads to a prediction with a confidence interval, but in the present study, EER was used as a constant in the calculation of the ratios.

Because this analysis is based on only the first 24-hour recall of energy intake, day-to-day variations are not taken into account. However, the usual intake of a population is typically benchmarked on the average of the first 24-hour recall for that population. Consequently, daily intake can be used to assess energy under-reporting if the analysis is restricted to group or multiple group averages.

The regression results are multiple group comparisons and have been used to identify characteristics that are associated with under-reporting; they are not meant as predictive equations for individual under-reporting.

Another limitation of the study is that it was not possible to account for psychological factors associated with eating, such as social desirability, self-image and weight, and the fear of being negatively evaluated, all of which have been linked to energy under-reporting.[5,6] Nor is it known if CCHS respondents were on a diet or were limiting their food intake when they were interviewed. Reports of energy intake are always subject to the possibility of under- or overeating on a particular day.

Conclusion

The results of the present study are important for users of the CCHS nutrition data, who, before undertaking an analysis, should be aware that subgroups have variable degrees of energy under-reporting. It is helpful not only to determine the extent of under-reporting, but also to identify groups whose energy intake is under-reported, over-reported, or plausible. Identifying these respondents is the topic of another article.[15] ■

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Impact of identifying plausible respondents on the under-reporting of energy intake in the Canadian Community Health Survey

by Didier Garriguet

Abstract

Background
Under-reporting is common in nutrition surveys. The identification of plausible respondents is a way of measuring the impact of under-reporting on the relationship between energy intake and body mass index (BMI).

Data and methods
A 24-hour dietary recall from 16,190 respondents aged 12 or older to the Canadian Community Health Survey (CCHS) - Nutrition was used to determine energy and nutrient intake. To identify plausible respondents, a confidence interval was applied to total energy expenditure derived from equations developed by the Institute of Medicine. Estimates of energy and nutrient intake for plausible respondents were compared with estimates for all respondents. Linear regression was used to demonstrate the impact of under-reporting on the relationship between reported energy intake and weight. Logistic regression was used to determine the impact of under-reporting on modelling the characteristics of obese people.

Results
With a confidence interval of 70% to 142% around energy expenditure, 57% of CCHS respondents were identified as "plausible respondents." Nutrient under-reporting varied between 1% and 10%. Analysis based only on plausible respondents re-establishes the theoretical relationship between energy intake and body weight, a relationship that is lost when analysis is based on the full sample.

Interpretation
Identifying plausible respondents is an effective way of measuring the impact of under-reporting food intake. Conclusions based on plausible respondents, rather than on all respondents, are more in line with theoretical expectations, such as a positive association between high energy intake and obesity.

Keywords

caloric intake, diet, food habits, energy expenditure, energy metabolism, nutrition surveys, obesity, twenty-four-hour recall, under-reporting

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The 2004 Canadian Community Health Survey (CCHS)–Nutrition was the first national survey of the eating habits of the Canadian population since the early 1970s. One of the objectives of the 2004 CCHS was to determine the intake of energy (calories), macronutrients (fats, proteins and carbohydrates) and micronutrients (vitamins and minerals) for different groups.

While every effort was made to ensure that the data were accurate—from questionnaire design through sampling and interviewer training to raw data verification and validation—the CCHS, like most nutrition surveys, was subject to under-reporting.[1-6] For a number of reasons (forgetfulness, social desirability, self-image, fear of being negatively judged[5,6]), respondents may deliberately or inadvertently report that they ate and drank less than they actually did.

The CCHS used a well-established collection instrument, the Automated Multiple-Pass Method (AMPM),[7,8] to maximize respondents' recall of what they consumed the day before they were interviewed. However, as reported in a companion article,[9] under-reporting among the population aged 12 or older still amounted to an average of about 10% of total energy intake. Under-reporting was associated with a number of characteristics, notably, body mass index, age, sex, and physical activity.

The under-reporting of energy intake and of specific nutrients has implications for the analysis of CCHS data. For instance, relationships between the amount and types of food consumed and body mass index are obscured by under-reporting. This article aims to address such issues by identifying "plausible" respondents.

Methods

Data source

The 2004 Canadian Community Health Survey (CCHS)–Nutrition collected information about the food and nutrient intake of the household population at the national and provincial levels. It excluded members of the regular Canadian Forces; residents of the three territories; people living on Indian reserves, in institutions, and in some remote areas; and all residents (military and civilian) of Canadian Forces bases. Detailed descriptions of the CCHS design, sample and interview procedures are available in a published report.[10]

A total of 35,107 people completed an initial 24-hour dietary recall; a subsample of 10,786 completed a second recall three to ten days later. Response rates were 76.5% and 72.8%, respectively. The energy and nutrient composition of the foods reported during each recall was determined according to Health Canada's Canadian Nutrient File (2001b Supplement).[11]

The original intention of the CCHS was to weigh and measure all respondents aged 2 or older, but for various reasons, the weight and height of around 40% of them were not measured. To adjust for this non-response, another survey weight was created, based on respondent classes with similar socio-demographic characteristics. Because of the bias that has been observed between self-reported and measured data,[12,13] measured height and weight are preferable to self-reports. Therefore, respondents with measured height and weight data (with the appropriate survey weight) were used for this analysis.

This study pertains to 16,190 respondents aged 12 or older who answered the physical activity questions. Women who were pregnant or breastfeeding, people of very low weight (body mass index less than 18.5kg/m^2), and respondents with no or invalid dietary intakes were excluded.

Identifying plausible respondents

Identifying plausible respondents requires establishing lower and upper cut-offs for their total predicted energy expenditure; that is, a range for the amount of energy they could be expected to expend to remain at their measured weight. The total predicted energy expenditure of CCHS respondents was determined with the equations developed by the Institute of Medicine (IOM),[14] which model the energy expenditure derived from a doubly labelled water study based on age, height and weight (body mass index), and level of physical activity. Details about the derivation of physical activity from the CCHS and about the IOM equations are presented in the accompanying article on energy under-reporting.[9]

Every CCHS respondent was identified as a plausible respondent, an under-reporter or an over-reporter, based on a comparison of their total predicted energy expenditure with their reported energy intake. Goldberg et al.[15] were the first to suggest such an approach, by creating a confidence interval for physical activity level (PAL) based on coefficients of variation (CV) of subjects' energy intake (CV_{wEi}), the accuracy of the measurement of their basal metabolic rate (CV_{wB}), and the total variation in physical activity level (CV_{tP}). Black[16] developed a practical guide for using the cut-offs, and explained the method's limitations. McCrory et al. went further with a direct comparison of total predicted energy expenditure and measured energy intake. In an initial study, [17] the model of total energy expenditure used a limited database of only 93 individuals, whereas a second[18] used the IOM equations, which were developed with information from more than 700 individuals. Both cases assumed the "low active" physical activity category for all individuals. In the report, *What America Drinks*,[19] McCrory's method was modified to produce larger intervals for plausible intakes by assuming four different levels of physical activity for every individual.

For the present analysis, McCrory's intervals for the four levels of physical activity were applied to CCHS respondents according to the amount of activity each of them reported. That is, the interval applied to CCHS respondents depended on whether they were sedentary, low active, active or very active.

Table 1
Estimation of standard deviation (SD), by age group and sex, household population aged 12 or older, 2004

Age group and sex	Size of double-recall sample	CV^2_{rEI}	CV^2_{pER}	CV^2_{mTEE}	SD
Total	**5,581**	**32.6**	**10.6**	**8.2**	**35.3**
12 to 13					
Male	298	30.3	5.4	8.2	31.8
Female	257	28.3	7.4	8.2	30.4
14 to 18					
Male	566	33.2	4.8	8.2	34.5
Female	583	33.6	7.2	8.2	35.4
19 to 30					
Male	402	36.0	10.4	8.2	38.3
Female	552	35.9	10.5	8.2	38.3
31 to 50					
Male	410	31.9	11.0	8.2	34.7
Female	512	34.2	10.8	8.2	36.8
51 to 70					
Male	434	32.8	11.7	8.2	35.8
Female	619	33.3	11.6	8.2	36.2
71 or older					
Male	331	28.4	13.3	8.2	32.4
Female	617	29.1	13.4	8.2	33.0

Note: CV^2_{rEI} is within-individual variation in reported energy intake. CV^2_{pER} is within-individual variation in predicted energy requirement. CV^2_{mTEE} is within-individual variation in measurement error and day-to-day variation in total energy requirement (TEE).
Sources: 2004 Canadian Community Health Survey - Nutrition.

The confidence interval for the ratio of measured energy intake (rEI) to the predicted energy requirement (pER) was constructed from the standard deviation (SD), defined as follows:

$$SD = \sqrt{CV_{rEI}^2 / d + CV_{pER}^2 + CV_{mTEE}^2}$$

where CV_{rEI}^2 represents the intra-individual variation of energy intake; d the number of days of recall; CV_{pER}^2, the error in predicted energy requirements; and CV_{mTEE}^2, the day-to-day variation and the measurement error for total energy expenditure based on doubly labelled water.

Black and Cole[20] estimated CV_{mTEE}^2 at 8.2%, which was used in the present study. CV_{rEI}^2 and CV_{pER}^2 came from the CCHS data. CV_{rEI}^2 came from the respondents who provided two dietary recalls, based on the formula:

$$CV_{rEI}^2 = \sqrt{\sum_{i=1}^{n} (CV_i^2)/n}$$

where CV_i is the CV calculated for every individual. CV_{pER}^2 was obtained by dividing the average standard error of individual predictions for a group by the average prediction of energy expenditure for that group.

The CCHS obtained two dietary recalls for approximately 30% of the sample, but only the first is used in the subsequent analysis. Therefore, *d*=1, and an average SD value of 35% is used (Table 1).

Because the energy intake distribution is skewed, the confidence intervals were constructed in the log scale, and the cut-offs were exponentiated. The confidence interval for the energy intake to energy expenditure ratio (EI:EE) for plausible respondents is

$$EI{:}EE \in [\exp(-\alpha * SD);\ \exp(\alpha * SD)]$$

A multiplicative factor α can be applied to the SD to construct the confidence interval. This study uses only the multiplicative factor of 1.

Respondents whose reported energy intake was less than 70% of their predicted energy expenditure were classified as under-reporters; if the figure was more than 142% of their predicted energy expenditure, they were classified as over-reporters. Plausible respondents were those whose energy intake was 70% to 142% of their predicted energy expenditure. The representativeness of this sample of plausible respondents was assessed by comparing their socio-demographic characteristics with those of the total sample.

Analytical techniques

When plausible respondents had been identified, under-reporting of energy and nutrient intake was determined by dividing estimates for plausible respondents by estimates for all respondents.

Linear regression was used to demonstrate the impact of under-reporting on the relationship between reported energy intake and weight for the total population and for plausible respondents. Logistic regression was used to determine the impact of under-reporting on modelling the characteristics of obese people. The bootstrap method, which takes the complex design of the CCHS into consideration,[21-23] was used to estimate the confidence intervals of estimated ratios and odd ratios. The significance level was set at $p < 0.05$.

Definitions

Three types of covariates were included in this study: lifestyle risk factors, health status, and socio-demographic characteristics.

Body mass index (BMI) is calculated by dividing weight in kilograms by the square of height in metres. In this analysis, the BMI categories for adults were based on Health Canada guidelines.[24] People whose BMI was between 18.5 kg/m^2 and 24.99 kg/m^2 were normal weight; between 25

Table 2
Slope of weight variable in modelling predicted energy expenditure or energy intake for all respondents and for plausible respondents, by age group and sex, household population aged 12 or older, Canada excluding territories, 2004

Age group and sex	Predicted energy expenditure model	Energy intake model: All respondents	Energy intake model: Plausible respondents
12 to 13			
Male	27.01	2.34 *	19.97*
Female	18.52	-13.13 *	6.13*
14 to 18			
Male	24.94	-1.43 *	20.43*
Female	17.84	-6.63 *	7.97*
19 to 30			
Male	16.24	-9.25 *	12.58
Female	13.88	2.58 *	11.14
31 to 50			
Male	17.20	4.01 *	12.22*
Female	13.15	1.23 *	9.58
51 to 70			
Male	16.16	-1.87 *	9.57*
Female	13.15	-2.30 *	7.19*
71 or older			
Male	16.99	5.20 *	19.53
Female	13.43	-2.82 *	9.95*

* significantly different from slope estimate of predicted energy expenditure model ($p < 0.05$).
Note: Ratio of energy intake (EI) to energy expenditure (EE) of plausible respondents is between 0.70 and 1.42.
Source: 2004 Canadian Community Health Survey – Nutrition.

kg/33m^2 and 29.99 kg/m^2, overweight; and more than 30 kg/m^2, obese. For adolescents aged 12 to 17, the categories defined by Cole *et al.*[25] were used.

Four levels of *leisure-time physical activity* were determined: sedentary, low active, active, and very active.

Alcohol consumption refers to the 12 months before the CCHS interview.

Fruit and vegetable consumption was based on the reported usual frequency of consumption, not the 24-hour recall. It represents the number of times per day respondents consumed fruit and vegetables, not the amount of food consumed.

Smokers are those who reported that they smoke daily or occasionally.

The variables related to health status were *self-reported health* (excellent, very good, good, fair and poor) and the presence of at least one *chronic condition*.

The socio-demographic variables were: *sex* and *age*, based on the IOM dietary reference groups; *highest level of education in the household* (less than secondary graduation, secondary graduation, some postsecondary, postsecondary graduation); *household income* from all sources and accounting for household size (low, low/middle, middle, middle/high, and high); *employment status* the week before the interview; *immigrant* and *Aboriginal* status; and *province of residence*.

Results

One-third under-report

If an analysis uses only data for plausible respondents, the cost in terms of sample size may be high. Based on the confidence interval of 70% to 142% around the ratio of reported energy intake to predicted energy expenditure, 9,196 (57%) of CCHS respondents were identified as plausible respondents; 5,388 (33%) as under-reporters; and 1,606 (10%) as over-reporters.

The characteristics of plausible respondents did not differ significantly from those of the total population (Appendix Table A). However, significant differences between plausible respondents and under- and over-reporters emerged in relation to BMI, physical activity, highest level of education in the household, and province. These differences persisted in a logistic regression model (data not shown).

Association between reported energy intake and weight

The biological relationship between energy intake and weight is obvious: if weight is to be maintained, long-term energy expenditure must match long-term energy intake. The higher the weight, the higher the energy expenditure, and the greater the energy intake. Thus, in theory, the regression coefficients between weight and predicted energy expenditure requirements, and between weight and energy intake should be the same.

Table 2 shows the slope of weight in the model of total predicted energy *expenditure.* Because predicted energy

Table 3
Under-reporting of selected nutrients, household population aged 12 or older, Canada excluding territories, 2004

	Average or percentage		Under-reporting		
Nutrients	All respondents	Plausible respondents	% difference between plausible and all respondents	95% confidence interval from	95% confidence interval to
Energy (kilocalories)	2,173	2,349	8.1	6.6	9.6
Proteins (grams)	87.6	92.6	5.7	3.9	7.6
% of calories	16.2	15.6	-3.3	-4.5	-2.2
Carbohydrates (grams)	270	291	8.0	6.4	9.5
% of calories	49.7	49.2	-0.9	-1.6	-0.3
Fats (grams)	79.4	86.8	9.3	7.4	11.3
% of calories	31.5	32.4	2.8	2.0	3.7
Monounsaturated fats (grams)	31.9	35.0	9.7	7.5	11.9
% of calories	12.6	13.0	3.7	2.7	4.7
Polyunsaturated fats (grams)	14.0	15.3	9.0	6.6	11.4
% of calories	5.6	5.7	2.8	1.4	4.1
Saturated fats (grams)	25.9	28.3	9.4	7.3	11.5
% of calories	10.3	10.6	2.7	1.4	3.9
Alcohol (grams)	9.2	10.1	8.8	1.1	16.6
Caffeine (milligrams)	210	211	0.6	-2.8	4.0
Water (grams)	2,765	2,833	2.4	1.2	3.7
Cholesterol (milligrams)	285	301	5.5	3.0	8.0
Dietary fibre (grams)	17.5	18.5	6.1	4.2	8.0
Sugar (grams)	111	121	9.6	7.8	11.5
Vitamin D (micrograms)	5.9	6.3	7.3	3.0	11.7
Vitamin C (milligrams)	131	140	6.9	4.3	9.4
Vitamin B12 (micrograms)	4.5	4.6	3.3	-1.6	8.2
Vitamin B6 (milligrams)	1.9	2.0	5.1	3.1	7.2
Vitamin A (micrograms)	713	759	6.4	2.5	10.4
Niacin (milligrams)	40.5	42.8	5.6	3.8	7.4
Riboflavin (milligrams)	2.0	2.1	7.2	5.6	8.8
Thiamin (milligrams)	1.8	1.9	6.8	4.9	8.8
Dietary folate equivalent (micrograms)	474	510	7.5	5.7	9.2
Folic acid (micrograms)	128	138	8.3	5.2	11.3
Naturally occurring folate (micrograms)	237	252	6.4	4.6	8.2
Calcium (milligrams)	907	983	8.3	6.4	10.2
Sodium (milligrams)	3,222	3,429	6.4	4.7	8.2
Iron (milligrams)	14.7	15.6	6.1	4.3	8.0
Magnesium (micrograms)	331	352	6.2	4.7	7.7
Phosphorus (milligrams)	1,387	1,479	6.7	5.0	8.3
Potassium (milligrams)	3,156	3,331	5.6	4.1	7.1
Zinc (milligrams)	11.6	12.3	5.7	3.7	7.7

Note: Ratio of energy intake (EI) to energy expenditure (EE) of plausible respondents is between 0.70 and 1.42.
Source: 2004 Canadian Community Health Survey – Nutrition.

Table 4
Ratio of energy intake and predicted energy expenditure of all respondents and plausible respondents, by body mass index (BMI) category, age group and sex, household population aged 12 or older, Canada excluding territories, 2004

	All respondents		Plausible respondents	
	Ratio EI:EE	Standard error	Ratio EI:EE	Standard error
Total	0.904	0.007	0.984	0.005
Body mass index category				
Normal	1.00	0.01	1.01	0.01
Overweight	0.87	0.01	0.97	0.01
Obese	0.79	0.01	0.96	0.01
Age group and sex				
12 to 13				
Male	1.01	0.03	1.02	0.01
Female	0.99	0.03	1.01	0.02
14 to 18				
Male	0.98	0.02	0.99	0.01
Female	0.95	0.02	1.00	0.01
19 to 30				
Male	0.96	0.02	0.98	0.01
Female	0.87	0.02	0.99	0.01
31 to 50				
Male	0.92	0.02	1.00	0.01
Female	0.88	0.02	0.97	0.01
51 to 70				
Male	0.88	0.02	0.99	0.01
Female	0.86	0.01	0.97	0.01
71 or older				
Male	0.84	0.02	0.96	0.02
Female	0.89	0.02	0.97	0.01

Note: Ratio of energy intake (EI) to energy expenditure (EE) of plausible respondents is between 0.70 and 1.42.
Source: 2004 Canadian Community Health Survey – Nutrition.

expenditure depends on body weight, the relationship would be expected to be strong. In fact, this is borne out, with the R^2 ranging from 0.51 to 0.77 (data not shown).

Table 2 also shows the slope of weight in the model of energy *intake* for all respondents and for plausible respondents. For all respondents, not only are all the slopes significantly different from the slope for total energy expenditure, but for 7 of the 12 age/sex groups, the slope is negative, indicating that the higher their measured weight, the lower their reported energy intake. In these models, R^2 never exceeds 0.04 (data not shown).

By contrast, for plausible respondents, the slope of weight is always positive. All slopes are closer to the theoretical biological relationship (the higher the weight, the greater the energy intake), and there is no significant difference from the energy expenditure model for 4 of the 12 age/sex groups. Therefore, when based on plausible respondents, the quality of the energy intake model improves, with the R^2 ranging from 0.02 to 0.24 (data not shown).

Impact on reporting of nutrient intake

A comparison of the average reported consumption of a nutrient for all respondents with that for plausible respondents provides an estimate of the extent to which consumption of that nutrient is under-reported (Table 3). For example, based on the reported calorie intake of all respondents versus plausible respondents, the average rate of energy under-reporting is 8.1%, which is close to the 9.6% estimated in the accompanying article.[9] Under-reporting of fat and sugar consumption amounts to 9.3% and 9.6%, respectively. Calcium (8.3%) and alcohol (8.8%) are also under-reported. (Negative values indicate that intake of the nutrient is over-reported by the total population.)

The ratio of reported energy intake to energy expenditure (EI:EE) is higher for plausible respondents (0.98) than for all respondents (0.90) (Table 4). Regardless of age and sex, the ratios for plausible respondents are higher, ranging from 0.96 to 1.02, compared with 0.84 to 1.01 for the total population. Even among obese people, who tend to under-report, the ratio is 0.96 for those identified as plausible respondents, compared with 0.79 for all respondents.

Impact on modelling obesity

The substantial under-reporting of food and beverage consumption in the CCHS has implications for analysis of the data. For example, the relationship between energy intake (calories consumed) and obesity among people aged 18 or older differs depending on whether the results are based on all respondents or on plausible respondents. Based on all respondents, no significant association emerges between calorie consumption and obesity (Table 5). However, the use of only plausible respondents yields a positive and significant association between obesity and calories consumed for both sexes.

Discussion

The main strength of this study is the large sample size. Even excluding under- and over-reporters, the number of plausible respondents is large enough and representative enough to permit a detailed analysis. As well, the availability of measured height and weight data obviated the need to account for the response bias associated with self-reports of these variables. Finally, the analysis incorporates a physical activity variable and considers several levels of activity when predicting energy expenditure requirements.

Table 5
Adjusted odds ratios relating energy intake and selected characteristics to obesity among all respondents and among plausible respondents, household population aged 18 or older, Canada excluding territories, 2004

	Male						Female					
	All respondents			Plausible respondents			All respondents			Plausible respondents		
Nutrients	Adjusted odds ratio	95% confidence interval from	to	Adjusted odds ratio	95% confidence interval from	to	Adjusted odds ratio	95% confidence interval from	to	Adjusted odds ratio	95% confidence interval from	to
Energy intake (in 100s of kcal)	0.99	0.98	1.01	1.10*	1.06	1.14	1.00	0.99	1.02	1.16*	1.12	1.20
Leisure-time physical activity												
Sedentary	1.20	0.80	1.79	1.21	0.67	2.19	1.61*	1.17	2.23	2.52*	1.55	4.10
Low active†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Active	0.86	0.47	1.58	0.59	0.22	1.63	0.39*	0.22	0.72	0.18*	0.06	0.51
At least one chronic condition												
Yes	1.61*	1.19	2.17	1.50	0.97	2.32	1.50*	1.18	1.92	1.38	0.92	2.08
No†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Education												
Less than secondary graduation	1.48	0.95	2.30	1.97*	1.09	3.55	1.36	0.99	1.89	1.59	0.96	2.66
Secondary graduation	1.05	0.72	1.53	1.42	0.85	2.38	1.36	0.90	2.07	1.22	0.68	2.18
Some postsecondary	1.14	0.69	1.89	1.48	0.71	3.09	2.32*	1.57	3.42	2.79*	1.48	5.26
Postsecondary graduation†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Self-reported health												
Excellent†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Good	1.30	0.87	1.94	0.89	0.51	1.56	1.45*	1.02	2.08	2.38*	1.42	4.00
Average	1.99*	1.28	3.08	1.74	0.92	3.30	2.50*	1.73	3.62	3.50*	1.98	6.19
Fair	2.76*	1.61	4.74	2.73*	1.19	6.26	2.77*	1.88	4.07	3.48*	1.85	6.56
Poor	3.39*	1.17	9.78	5.11*	1.38	19.01	2.46*	1.22	4.93	3.23*	1.17	8.89
Immigrant												
Yes	0.55*	0.38	0.81	0.60*	0.36	0.99	0.73	0.51	1.04	0.95	0.55	1.63
No†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Aboriginal												
Yes	1.25	0.57	2.70	1.29	0.44	3.77	1.92*	1.16	3.18	2.08	0.97	4.47
No†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Household income												
Low†	0.52	0.22	1.25	0.48	0.13	1.73	0.84	0.46	1.54	0.37*	0.17	0.79
Low/Middle	0.43*	0.20	0.90	0.39	0.14	1.07	0.88	0.53	1.47	0.86	0.39	1.93
Middle	0.76	0.48	1.20	0.95	0.51	1.78	1.21	0.84	1.75	1.30	0.74	2.28
Middle/High	0.90	0.65	1.25	1.03	0.64	1.67	1.04	0.75	1.45	1.05	0.63	1.75
High†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
Age group												
18 to 30†	1.00	...	...	1.00	...	...	1.00	...	...	1.00	...	...
31 to 50	1.74*	1.23	2.45	2.56*	1.52	4.31	1.72*	1.23	2.39	2.14*	1.21	3.78
51 to 70	1.95*	1.34	2.84	3.22*	1.91	5.42	2.15*	1.52	3.05	3.11*	1.64	5.88
71 or older	0.85	0.52	1.39	1.66	0.78	3.52	1.19	0.80	1.77	2.17*	1.10	4.26

† reference category
* significantly different from estimate for reference category ($p < 0.05$)
... not aplicable
Note: Also adjusted for alcohol consumption in past 12 months, daily fruit and vegetable consumption, province, and smoking status. Categories for missing values for education and household income and the very active category for physical activity were included, but the odds ratios are not shown. The ratio of energy intake (EI) to energy expenditure (EE) for plausible respondents is between 0.70 and 1.42.
Source: 2004 Canadian Community Health Survey – Nutrition.

It would have been possible to assume, as was done by McCrory *et al.*[17] and Huang *et al.*,[18] that all respondents were "low active." This would result in a slightly smaller sample of plausible respondents (56%), but 96% of CCHS respondents would still be classified in the same category (under-reporter, over-reporter or plausible respondent) as in the present study. The difference lies in the representativeness of the sample, which would be slightly less if a single physical activity level had been used.

Another option for estimating physical activity would have been to use the method employed in *What America Drinks,*[19] whereby the lower confidence interval limit is set based on the assumption of a sedentary level of physical activity, and the upper confidence interval limit is set assuming a very active level of physical activity. The result is that a much larger proportion of the CCHS sample—74%—would be considered to be plausible respondents, including every plausible respondent identified in the present study. The drawback is that this method is less effective in correcting the distortion in the biological relationship between energy intake and body weight, and the relationship between energy intake and obesity in the logistic model is weaker.

An alternative is the Goldberg cut-offs for physical activity level (PAL) using the ratio of energy intake and predicted basal metabolic rates from the Schofield equations.[26] Using the same SD, with a basic comparative PAL of 1.55 and a multiplicative factor of 1, yields a slightly smaller sample of plausible respondents (54%) than in the present study. While the classification of respondents as under- and over-reporters and plausible respondents is the same for 90% of the sample, the representativeness of the plausible respondents is not as good.

The confidence intervals in this study were exponentiated, whereas McCrory *et al.*[17] and Huang *et al.*[18] used a ±35 % confidence interval. Application of the latter to the CCHS data would shift the confidence interval toward more under-reporters and fewer over-reporters, although 92% of respondents would still be classified in the same category as in the present study. The difference is in the level of correction of the energy intake to energy expenditure ratio (EI:EE). Instead of increasing the average EI:EE ratio for plausible respondents to 0.98, as is the case when using the log scale, a symmetrical confidence interval yields an average EI:EE ratio of 0.94.

Huang *et al.*[18] used virtually the same method as that employed in the present study to identify plausible respondents in the 1994-1996 Continuing Survey of Food Intakes by Individuals (CSFII). They identified plausible respondents through an optimal confidence interval of ± 30.8% corresponding to 1.4 times the standard deviation (SD). McCrory *et al.*[17] used somewhat different predictive equations, but their confidence interval of ± 1 SD corresponded to ± 30%. In both cases, their confidence interval is similar to the one obtained in this analysis. The difference stems from the fact that the CSFII has a smaller CV for the energy intakes, compared with the Canadian population.

Limitations

A major limitation of the present study is that predicted energy expenditure requirements are based on a model constructed by the Institute of Medicine using a sample of about 700 people of different ages and levels of physical activity; very active people and some specific ages are under-represented in that sample.

The level of physical activity measured in the CCHS is self-reported. As well, it refers only to leisure time; work- or transportation-related physical activity is not included.

Excluding under- and over-reporters from an analysis also excludes some plausible respondents who happened to eat much more or much less than usual on the dietary recall day. Even so, on the basis of their socio-demographic characteristics, those who were identified as plausible respondents are representative of the total population.

Conclusion

It is essential to consider under-reporting in analyses of data from nutrition surveys, especially when examining relationships between diet and variables that are highly correlated with under-reporting, such as body mass index. This study shows that just over half of respondents to the Canadian Community Health Survey reported food and beverage consumption that was "plausible," given their height, weight, and level of physical activity. Fully a third were "under-reporters," in that what they reported that they ate and drank could not sustain their measured weight. Under-reporting was particularly common among people who were obese, and as a consequence, under-reporting tends to distort analyses of the relationship between energy intake and obesity.

This study confirms the findings of others, specifically McCrory *et al.*[17] and Huang *et al.*,[18] on the impact of under-reporting on the biological relationship between energy intake and weight, as well as on models related to body mass index. And because of the large CCHS sample, these results can be confirmed for specific age and sex groups.

This study also validates the companion article on under-reporting.[9] The characteristics of under-reporters, compared with those of plausible respondents, are essentially the same as with the other method. Average energy under-reporting is slightly less in this analysis, but still in line with the results in the other article.

The technique employed in the present study has numerous applications. It can be used to analyze models related to body mass index and to estimate the level of under-reporting of nutrients, certain foods, and food groups. The results show that some foods are particularly susceptible to under-reporting. Future studies could attempt to better identify foods that are under-reported and occasions when the food consumed may not be reported. ■

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Appendix

Table A
Selected socio-demographic characteristics of plausible respondents, under-reporters and over-reporters, household population aged 12 or older, Canada excluding territories, 2004

Characteristics	All respondents	Plausible respondents	Under-reporters	Over-reporters
Average age (years)	42.9	42.6	44.5*	39.6*
			%	
Sex (female)	49.5	49.6	50.6	44.8
Body mass index category				
Normal	42.3	44.8	31.9*	61.4*
Overweight	35.3	35.1	37.8	29.0*
Obese	22.4	20.1	30.3*	9.6*
Leisure-time physical activity				
Sedentary	18.4	18.5	16.1	24.9*
Low active	74.5	75.2	75.0	69.5*
Active	6.6	5.9	8.2*	5.4[E]
Very active	0.5	0.5[E]	0.7[E]	F
Education				
Less than secondary graduation	9.8	9.1	11.1*	10.0
Secondary graduation	10.5	9.8	12.8*	7.6
Some postsecondary	7.2	7.1	8.0	5.3
Postsecondary graduation	70.3	71.8	66.1*	75.2
Daily fruit and vegetable consumption				
Fewer than 5 servings	68.0	67.2	70.8*	63.4
5 to 10 servings	30.4	31.3	27.6*	34.4
More than 10 servicing	1.3	1.0[E]	1.4[E]	F
Household income				
Low	2.6	2.1	3.3*	2.7
Low/Middle	5.6	5.4	6.2	4.8
Middle	19.3	19.0	20.3	17.3
Middle/High	33.1	33.3	31.5	37.4
High	30.4	31.4	29.6	27.3
Province				
Newfoundland and Labrador	1.7	1.7	1.9	1.3[E]
Prince Edward Island	0.4	0.4	0.5*	0.3[E]
Nova Scotia	3.0	3.2	2.9	2.1*[,E]
New Brunswick	2.4	2.5	2.5	1.7*
Quebec	24.0	25.8	18.3*	32.2*
Ontario	39.0	37.5	43.6*	32.0*
Manitoba	3.5	3.3	4.0*	2.9
Saskatchewan	2.9	2.8	3.3	2.5[E]
Alberta	9.8	9.2	10.8*	9.4
British Columbia	13.3	13.5	12.2	15.6

* significantly different from estimate for plausible respondents ($p < 0.05$)
... not aplicable
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: Ratio of engery intake (EI) to energy expenditure (EE) of plausible respondents is between 0.70 and 1.42.
Source: 2004 Canadian Community Health Survey – Nutrition.

The concentration-coverage curve: A tool for ecological studies

by Philippe Finès

Abstract

Background
A selective approach may be used in an ecological study where the aim is to choose a subset of units of analysis (UAs) and produce interpretations about a population of interest (PI) based solely on those UAs. The results for the PI will be reliable if that population is concentrated in the selected UAs and rare in other UAs. This article presents a graphical tool that helps determine whether these conditions are satisfied.

Data and methods
Data on the Inuit and Métis ancestry populations from the 1996 Census of Canada are used for illustrative purposes. Based on a classification statistics table, a concentration-coverage curve can be created for a given PI. The shape of the curve indicates whether it is possible to choose a threshold that will yield both adequate concentration and adequate coverage of the PI.

Results
The concentration-coverage curve shows that, among Aboriginal peoples living in rural areas, the Inuit population is classifiable, but the Métis population is not.

Interpretation
This method can be applied to any ecological study focussing on the proportion of individuals sharing a single characteristic defined by a binary variable.

Keywords
classification, demography, ecological studies, population distribution

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In ecological studies, individuals are grouped into units of analysis (UAs) rather than being considered separately. In certain instances, a researcher may wish to employ UAs to make inferences about a population, but there is a potential for error if the population of interest (PI) is not sufficiently represented in those UAs. A selective approach is used when the aim is to choose a subset of UAs and produce interpretations about a PI based solely on those UAs. If the selected UAs contain only PI individuals, and if PI individuals are present only in those UAs, the selective approach is obviously valid in that it yields results from which it is possible to draw conclusions about the PI.

In most instances, however, it is not easy to determine if the selective approach is valid, and it is important to know if the selected UAs adequately represent the PI; that is, whether the PI is highly concentrated in those UAs and rare in the UAs that were not selected. This article offers a method of determining if these conditions exist.

A detailed description of the proposed method is presented, along with an illustration of how it applies to studies of the Aboriginal peoples of Canada, specifically, Inuit and Métis living in rural areas. The method is compared with related classification methods, and other considerations are discussed.

Definitions

For situations in which the selected UAs are known,

- "proportion" (for a given UA) is defined as the number of PI individuals divided by the total number of individuals;

- "concentration" is the number of PI individuals divided by the total number of individuals in the selected UAs; and
- "coverage" is the number of PI individuals in the selected UAs divided by the total number of PI individuals.

Based on these concepts, a PI is "classifiable" (and therefore, the selective approach is valid) if a threshold α (between 0 and 1) can be chosen such that selecting only UAs in which the PI makes up a proportion at least equal to α yields both high concentration and high coverage of the PI. For purposes of illustration, two Aboriginal groups—Inuit and Métis—are considered as the PI, and Census Enumeration Areas (EAs) as the UAs.

Preliminary steps

The method of determining if a PI is classifiable is based on the complete list of UAs, sorted in ascending order according to the proportion of their population who are members of the PI. Each line in the list corresponds to one UA and contains: the number of PI individuals in the UA, the total population of the UA, and the proportion of the total who are members of the PI. (Because Canada contains 42,926 Census Enumeration Areas, it would be impractical to include the entire list in this article. It is available from the author on request.) The procedure is as follows:

- Choose a line, i, from the list.
- Add the number of PI individuals from line i to the bottom of the list and divide that sum by the total number of PI individuals. The result is the *coverage* of the PI given by all the UAs in which the PI proportion is at least equal to the proportion in line i.
- Divide the same numerator (the number of PI individuals from line i to the bottom of the list) by the total number of individuals in the UAs from line i to the bottom. The result is the *concentration*, determined by all UAs in which the PI proportion is at least equal to the proportion in line i.
- Consider another line, j, from the list such that line j has a higher PI proportion than line i (that is, line j is further down the list). By design, line j has lower *coverage* but higher *concentration* than line i.

The classification statistics table

From the list of UAs, it is possible to produce the classification statistics table.

Table 1
Classification statistics,† Inuit ancestry population

Threshold α	Number of Enumeration Areas (EAs) selected (EAs in which proportion of individuals in population of interest ≥α)	Total number of individuals in selected EAs	Number of individuals in selected EAs who are members of population of interest	Proportion of individuals in selected EAs who are members of population of interest = Concentration	Number of individuals in selected EAs who are members of complementary population	Proportion of individuals in selected EAs who are members of complementary population	Coverage = Sensitivity	Specificity	Complement of specificity
(1)	(2)	(3)	(4) = A	(5) = (4)/(3)	(6) = (3)-(4) = B	(7) = (6)/(3)	(8)= A/(A+C)	(9)=B/(B+D)	(10)=D/(B+D)
0.00	42,926	28,454,565=N	39,845 = A+C	0.00140	28,414,720=B+D	0.99860	1.00000	0.00000	1.00000
0.05	91	54,265	35,085	0.64655	19,180	0.35345	0.88054	0.99932	0.00068
0.10	75	48,230	34,665	0.71874	13,565	0.28126	0.87000	0.99952	0.00048
0.15	68	45,135	34,300	0.75994	10,835	0.24006	0.86084	0.99962	0.00038
0.20	65	42,885	33,875	0.78990	9,010	0.21010	0.85017	0.99968	0.00032
0.25	64	41,605	33,570	0.80687	8,035	0.19313	0.84251	0.99972	0.00028
0.30	63	40,715	33,335	0.81874	7,380	0.18126	0.83662	0.99974	0.00026
0.35	62	40,145	33,140	0.82551	7,005	0.17449	0.83172	0.99975	0.00025
0.40	61	39,920	33,055	0.82803	6,865	0.17197	0.82959	0.99976	0.00024
0.45	58	37,840	32,170	0.85016	5,670	0.14984	0.80738	0.99980	0.00020
0.50	56	37,005	31,775	0.85867	5,230	0.14133	0.79747	0.99982	0.00018
0.55	56	37,005	31,775	0.85867	5,230	0.14133	0.79747	0.99982	0.00018
0.60	54	35,990	31,200	0.86691	4,790	0.13309	0.78303	0.99983	0.00017
0.65	51	33,750	29,790	0.88267	3,960	0.11733	0.74765	0.99986	0.00014
0.70	50	33,380	29,540	0.88496	3,840	0.11504	0.74137	0.99986	0.00014
0.75	46	27,975	25,585	0.91457	2,390	0.08543	0.64211	0.99992	0.00008
0.80	43	26,555	24,480	0.92186	2,075	0.07814	0.61438	0.99993	0.00007
0.85	43	26,555	24,480	0.92186	2,075	0.07814	0.61438	0.99993	0.00007
0.90	35	21,600	20,110	0.93102	1,490	0.06898	0.50471	0.99995	0.00005
0.95	4	1,275	1,220	0.95686	55	0.04314	0.03062	1.00000	0.00000
1.00	0	0	0	...	0	...	0.00000	1.00000	0.00000

† numbers between 0 and 1 with five decimal places
... not applicable
Note: Letters correspond to cells in classification matrix (Table 2).
Source: 1996 Census of Canada.

This table (shown for the Inuit population in Table 1) is drawn from the list of UAs (only proportions that are multiples of 0.05 are shown). The rows correspond to the thresholds 0.00, 0.05, 0.10, … 1.00. (The row for threshold 0.00 is included for the sake of completeness, but it is not a threshold value that can be used). Columns (1) through (5) contain: threshold α, the number of UAs selected (that is, the number of UAs with a proportion at least equal to the threshold), the total number of individuals in the selected UAs, the number of PI individuals in the selected UAs, and the PI concentration in the selected UAs. Columns (6) and (7) pertain to the complementary population, and column (8) shows the PI coverage. Columns (9) and (10) and another interpretation of column (8) will be examined later, along with an explanation of letters A, B, C, D and N.

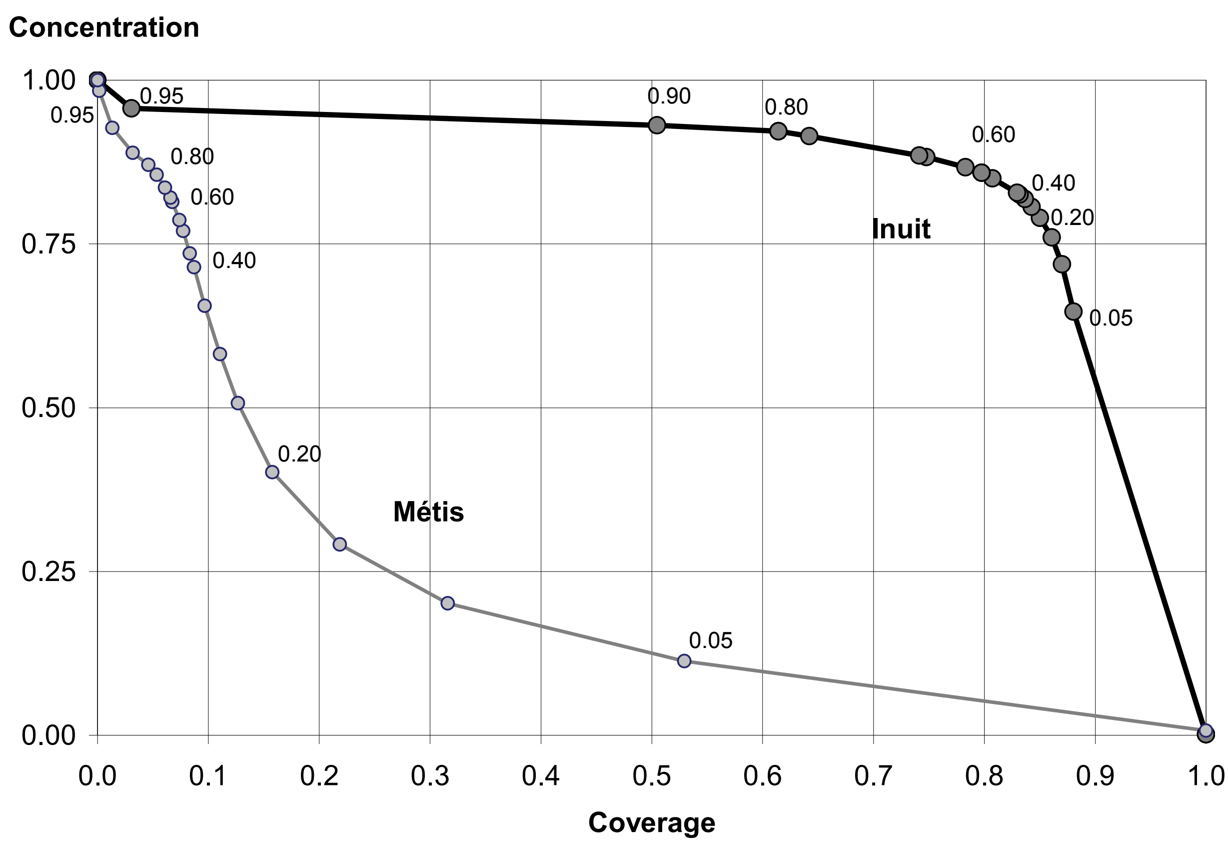
As the threshold increases, the number of UAs selected decreases. For example, when the threshold is 25%, the set of UAs in which the PI constitutes at least 25% of the population would be selected. A higher threshold would be more selective in that a smaller subset of UAs (all of which were included in the previous subset) would be selected. This new subset contains fewer individuals who are members of the PI, but also fewer individuals who are not members.

This reasoning can be summarized as follows: moving down the rows of the classification statistics table increases the threshold, which lowers coverage (from a maximum of 1) and increases concentration (up to a value less than or equal to 1). Consequently, if the threshold is too high, coverage of the PI may be insufficient; if the threshold is too low, a large number of individuals who are not members of the PI may be included, and concentration would then be reduced.

Constructing and interpreting the concentration-coverage curve

For a PI to be classifiable, it must be possible to choose a threshold that yields both adequate concentration and adequate coverage of the PI. To determine if these criteria are satisfied for a given PI, concentration is plotted in relation to coverage—the concentration-coverage curve (CC curve).

Figure 1
Concentration-coverage curve, Inuit and Métis populations living in rural areas, 1996



Note: The dots on the curves indicate threshold (α) values.
Source: 1996 Census of Canada.

The CC curves for the Inuit and Métis populations are shown in Figure 1: the dots on each curve represent a specific row in the classification statistics table. For the sake of clarity, the threshold value is indicated for some of the dots on the curves. (The classification statistics table for the Métis population is not shown in this article, but is available from the author on request). For the Inuit population CC curve, two pairs of thresholds (α = 0.50, 0.55 and α = 0.80, 0.85) correspond to the same number of EAs, so two pairs of dots have the same coverage (.80 and .61).

The upper left part of the Inuit population CC curve is almost horizontal and runs more than half the length of the X-axis: this part of the curve represents EAs with both high concentration and high coverage. Therefore, the shape of the curve indicates that selecting these EAs is sufficient for good classification of the Inuit population. For example, if the goal is 50% coverage, only EAs that yield a concentration of more than about 93% would be selected; in Table 1 and Figure 1, those are the EAs in which the proportion of the PI (that is, the Inuit population) is greater than or equal to a threshold of 0.90. A lower threshold is not necessary. (For 75% coverage, EAs that yield a concentration of 87% would be retained; this corresponds to a threshold of 0.60). Thus, according to the criteria stipulated above, the Inuit population is a classifiable PI. For example, the threshold used by Wilkins et al.[1] in their analysis of life expectancy in Inuit-inhabited areas was 33%, which resulted in both concentration and coverage around 80%.

The Métis population presents a very different picture. Unlike the Inuit population curve, the CC curve for the Métis population drops off sharply on the left and then flattens out (Figure 1). The shape of the curve indicates that it is impossible to find a threshold that yields both high coverage and high concentration of the Métis population: 50% coverage would require a relatively low concentration of 11% (obtained with a threshold of 0.05); at concentration of around 40%, coverage would scarcely reach 16% (with a threshold of 0.20). Therefore, unlike the Inuit population, the Métis population is not a classifiable PI, even though it is considerably larger (199,235 versus 39,845).

Table 2
Classification matrix

	Individuals who are members of population of interest	Individuals who are not members of population of interest	Total
Residents of units of analysis that were selected	A ("true positives")	B ("false positives")	A+B
Residents of units of analysis that were not selected	C ("false negatives")	D ("true negatives")	C+D
Total	A+C	B+D	N

Classification matrix

Table 1 demonstrates that as the threshold rises, the number of UAs that are selected declines, and the contents of column 3 (total population in the selected UAs), column 4 (number of PI individuals in the selected UAs) and column 6 (number of people in the selected UAs who do not belong to the PI) decline. At the same time, the average proportion of PI individuals in the UA increases.

These results can be explained by the concepts involved in classification theory. Classification involves two binary variables: UAs selected or not selected, and individuals who are members of the PI or who are not members of the PI (the complementary population). These variables can be illustrated in a classification matrix (Table 2). The N individuals in the Canadian population are distributed among the matrix's four cells as follows:

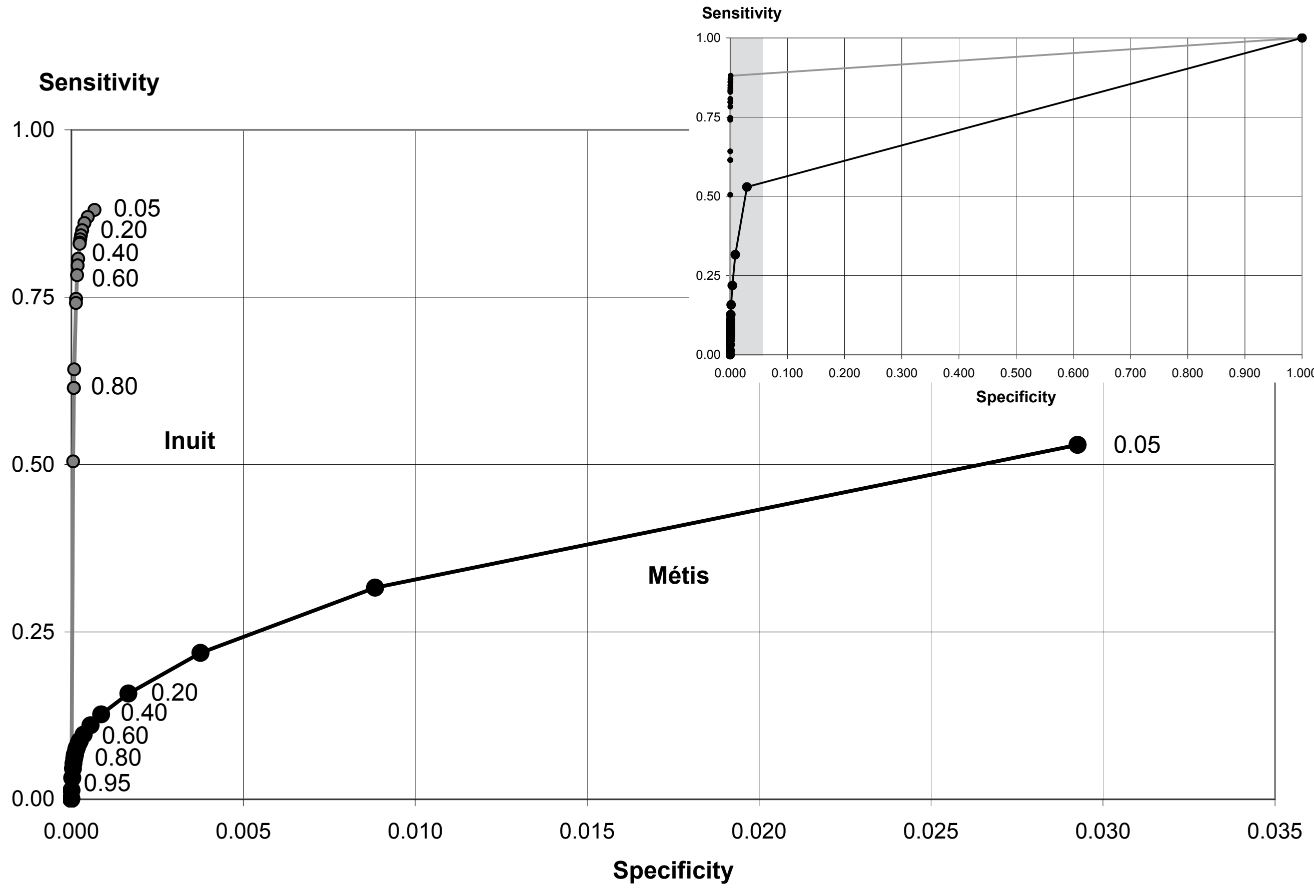
- Cell A contains the individuals who are members of the PI and live in a selected UA - "true positives."
- Cell B contains the individuals who are not members of the PI, but live in a selected UA - "false positives."
- Cell C contains the individuals who are members of the PI, but do not live in a selected UA - "false negatives."
- Cell D contains the individuals who are not members of the PI and do not live in a selected UA - "true negatives."

With higher thresholds, the values of A and B decrease, while C and D rise. The values of A+C, B+D and N, of course, remain the same. Hence, sensitivity, which is A/(A+C) and is simply another term for coverage, declines (column 8); specificity, which is D/(B+D), increases (column 9); and the complement of specificity declines (column 10).

Comparison with other curves

The information in the concentration-coverage curve can be displayed graphically in another type of curve—the receiver operating characteristic (ROC) curve. Commonly used in classification[2] the ROC curve captures the quality of a classification in relation to all of the selected thresholds. To construct it, sensitivity is plotted in relation to the complement of specificity. When the threshold rises, sensitivity and the complement of specificity decrease (movement down and to the left along the ROC curve). In other words, the lower left corner (coordinates

Figure 2
Receiver operating characteristics curve, Inuit and Métis populations living in rural areas, 1996



Note: Full graph is shaded portion of inset. The dots on the curves indicate threshold (α) values.
Source: 1996 Census of Canada.

0,0) corresponds to the highest threshold (1.00), and the upper right corner (coordinates 1,1) corresponds to the lowest threshold.

Figure 2 presents ROC curves for the Inuit and Métis populations. As in the CC curves, some of the values of thresholds are indicated with dots on the curves. Because Aboriginal people make up a small proportion of Canada's population (0.1% for the Inuit population, as indicated in row 0.00 of Table 1), very high specificity, and therefore, a very low value for the complement of specificity are invariably obtained in the ROC curve. (This is why Figure 2 shows two version of the ROC curve: the complete curve in the insert, and the one that excludes threshold 0.)

The ROC curve is an intuitive classification criterion: the closer a curve is to the upper left corner, the more classifiable is the PI. In Figure 2, the Métis population ROC curve is farther from the upper left corner than the Inuit population curve, which indicates that the Métis population is less classifiable than the Inuit population.

The CC curve, however, provides more information than the ROC curve, in that it is a qualitative visual means of determining whether a PI is classifiable. A PI whose CC curve remains roughly horizontal for some distance on the upper left side of the graph is classifiable; a PI whose CC curve falls sharply on the left is not classifiable. Also, in the case of particularly rare PIs such as the Inuit and Métis populations, displaying specific thresholds values in the ROC curve is difficult: the highest thresholds are stacked on the lower left part of the curve. By contrast, these thresholds are scattered along the CC curve.

Curves that are generally used to measure inequality, such as the Lorenz curve,[3] and Kakwani's income inequality curve,[4] contain an additional dimension (usually income) and do not serve the present purpose, which is to determine if a PI is classifiable. The CC curve uses a single variable—the PI proportion. The unique aspect of the CC curve is that the proportion is expressed with two different denominators.

Conclusion

This article provides a working definition of a classifiable PI: there must be at least one threshold value for which concentration (proportion of the population in the UAs who are members of the PI) and coverage (total proportion of PI accounted for by the selected UAs) are both sufficiently high. A qualitative visual representation of that concept is provided: if the PI is classifiable, the upper left of the CC curve is roughly horizontal.

In the example in this article, the PI is defined by an ethnic characteristic (Aboriginal ancestry). Clearly, this method can also be applied to any ecological study focussing on the proportion of individuals sharing a single characteristic, especially if that proportion is small. The characteristic could be, for example, a language, a behaviour or a disease.

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