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The 2015 Dietary Guidelines for Americans is associated with a more nutrient-dense diet and a lower risk of obesity[1–3]

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ABSTRACT

Background: Dietary pattern analysis represents a departure from the traditional focus on single foods and nutrients and provides a comprehensive understanding of the role of the diet in chronic disease prevention and etiology. Dietary patterns of Canadians have not been evaluated comprehensively with the use of an updated a priori dietary quality index.

Objectives: We aimed to update the Dietary Guidelines for Americans Adherence Index (DGAI) on the basis of the 2015 Dietary Guidelines for Americans (DGA), to evaluate the construct validity and reliability of the revised index, and to examine whether closer adherence to this index is associated with a lower risk of obesity with or without an accompanying chronic disease.

Design: Data from 11,748 participants (≥18 y of age) in the cross-sectional Canadian Community Health Survey cycle 2.2 were used in weighted multivariate analyses. Multinomial logistic regression was used to test the association between diet quality and obesity risk.

Results: With the use of principal component analyses, the multidimensionality of the 2015 DGAI was confirmed, and its reliability was shown with a high Cronbach's α = 0.75. Moving from the first to the fourth (healthiest) quartile of the 2015 DGAI score, there was a trend toward decreased energy (2492 ± 26 compared with 2403 ± 22 kcal, respectively; ±SE) and nutrients of concern (e.g., sodium), whereas intakes of beneficial nutrients increased (*P*-trend < 0.05). In the age- and sex-adjusted model, a lack of adherence to the 2015 DGA recommendations increased the OR of being unhealthy obese from 1.42 (95% CI: 1.02, 1.99) in quartile 3 to 2.08 (95% CI: 1.49, 2.90) in quartile 2 to 2.31 (95% CI: 1.65, 3.23) in the first quartile of the 2015 DGAI score, compared with the fourth quartile (healthiest) (*P*-trend < 0.0001). The odds of being obese without a chronic disease (healthy obese) and having a chronic disease without being obese also increased in the lowest DGAI quartile compared with the highest DGAI quartile, albeit not as much as in the unhealthy obese group.

Conclusion: The 2015 DGAI provides a valid and reliable measure of diet quality among Canadians. *Am J Clin Nutr* 2016;104:1378–92.

Keywords: Canada, chronic diseases, Dietary Guidelines for Americans Adherence Index, DGAI, dietary patterns, obesity, validity and reliability

INTRODUCTION

The prevalence of obesity and other chronic diseases worldwide increases drastically every year, and some researchers have attributed the failure in halting these epidemics to the extensive focus of preventive nutrition research on single foods and nutrients (1). An examination of dietary patterns has been increasingly recognized as an approach for informing public health recommendations, especially as methods for the assessment of dietary patterns are improved, and the evidence base is strengthened. A recent example is the US Department of Health and Human Services and USDA 2015–2020 Dietary Guidelines for Americans (DGA),[6] which has largely been informed by the evidence reviews of healthful dietary patterns rather than by single foods or nutrients (2). The use of a dietary pattern approach is also at the core of the conceptual models that have been adopted by the US National Cancer Institute (3) and the Australian Dietary Guidelines committee (4).

The first a priori dietary guidelines–related dietary quality index (5) was proposed by Kennedy et al. (6) to measure the

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[6] Abbreviations used: AUC, area under the receiver operating curve; CCHS 2.2, Canadian Community Health Survey cycle 2.2; CNF, Canadian Nutrient File; DGA, Dietary Guidelines for Americans; DGAI, Dietary Guidelines for Americans Adherence Index; EER, estimated energy requirement; EI, energy intake; IOM, Institute of Medicine; PAL, physical activity level; PCA, principal component analysis.

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degree of adherence to the 1995 DGA dietary recommendations (6). A priori methods measure the degree of adherence to national or international dietary guidelines and therefore are reproducible tools that are suitable for comparison (7).

To address the limitations of previous dietary indexes, Fogli-Cawley et al. (8) developed the 20-score 2005 Dietary Guidelines for Americans Adherence Index (DGAI), which is the only dietary guidelines-related index that is focused on both energy overconsumption and energy density (8). Instead of the one-size-fits-all approach of other dietary quality indexes, the DGAI evaluates diet quality in terms of adherence to the 12 USDA Food Patterns on the basis of individuals' energy needs (8). One of the advantages of the DGAI compared with other indexes is that individuals are penalized for overconsumption of energy-dense foods (i.e., starchy vegetables, grains, meat, and dairy) to limit the likelihood of receiving higher scores solely because of excessive food intakes (8). Adherence to the 2005 DGAI has been associated with reduced risks of several diseases, although the validity and reliability of this index has not been confirmed systematically (9–13).

To our knowledge, the dietary patterns of Canadians have not been comprehensively examined with the use of an a priori dietary guidelines–related dietary quality index mainly because of the lack of a "total diet" approach and energy-based dietary guidelines in Canada (14). The purpose of this study was to update the 2005 DGAI to reflect changes in the 2015 DGA and to evaluate its validity and reliability with the use of the Canadian national nutrition survey. This updated index was then used to evaluate whether closer adherence to the 2015 DGAI is associated with lower risk of obesity with and without an accompanying chronic disease (unhealthy and healthy obese), which is the underlying premise of the 2015 DGA. Although the scientific community has recognized the importance of differentiating obesity phenotypes, less attention has been given to this issue in nutritional epidemiology (15).

METHODS

Study population

Data used in this research were from the Canadian Community Health Survey cycle 2.2 (CCHS 2.2) (2004/2005), which provides the most complete nutritional data on Canadian dietary intakes and is the only available national nutrition survey in >30 y (16). Data were collected under the authority of the Statistics Act of Canada, and all analyses were conducted at the Statistics Canada's Research Data Center. The CCHS 2.2 is a complex, multistage, cross-sectional survey that included 35,107 Canadians from 10 provinces who represent >98% of the Canadian population (17). More details on the CCHS 2.2 sampling framework and survey procedures have been previously published (16). For the purpose of this study, all pregnant and lactating women, individuals <18 y of age, individuals with invalid dietary recalls (as defined by Statistics Canada), and individuals with missing values for physical activity, energy intakes (EIs), and measured weight and height were excluded. To be able to evaluate the face validity of the 2015 DGAI through its association with lifestyle and socioeconomic characteristics, individuals with missing values for these variables were also removed, which left a total of 11,748 Canadian adults for these analyses. The final sample represented the Canadian population homogenously considering that the general socioeconomic and lifestyle characteristics of participants who were included in the final analyses were similar to those who were excluded as a result of missing variables (data not shown).

Exposure and outcome ascertainment

A modified version of the USDA automated multiple-pass method was used to collect two 24-h dietary recalls (18, 19). Because the second recall was collected from 30% of the total population, only the first dietary recall was used in all analyses (16). Respondents reported all foods and beverages consumed in the past 24 h (midnight to midnight) and the nutrient composition of reported foods was analyzed with the use of Health Canada's Canadian Nutrient File (CNF) (2001b Supplement) (20). Because added sugars are not included in the CNF, the method proposed by Brisbois et al. (21) was used to derive estimates of added sugars. The dietary energy density was calculated by dividing the total energy from foods (kilocalories) by the total weight of foods (in grams) (with the exclusion of beverages) (22).

Data on sociodemographic characteristics and lifestyle behaviors were collected with the use of interviewer-administered questionnaires (16). Data-collection interviews and anthropometric measurements took place in person at the homes of participants (16). Height and weight were measured according to standard protocols, and BMI (in kg/m^2) was calculated. Overweight and obesity were defined as BMI ≥25–29.99 and ≥30, respectively. The presence of diabetes, hypertension, cardiovascular diseases, and cancer was determined with the use of self-report of a medical diagnosis or the presence of any chronic diseases.

DGAI

The DGAI is an a priori diet-quality index that assesses the adherence of dietary intakes to 20 main dietary recommendations of the 2005 DGA and USDA Food Patterns (8). In the current study, we revised the 2005 DGAI on the basis of the 2015 USDA Food Patterns and evaluated the construct validity and reliability of the revised index. The DGAI distinguishes between energy-specific dietary recommendations and healthy choice nutrient recommendations. Of 20 total DGAI components, 11 components evaluate energy-specific food intake recommendations (on the basis of the 12 energy-based USDA Food Patterns), whereas 9 components evaluate universal healthy choice nutrient recommendations (8). The food intake recommendations are specific to the energy needs of each individual, whereas healthy choice recommendations are presented in absolute amounts or the percentage of energy and are the same for all individuals (8).

In the current study, only 19 DGAI components were available because one component of the healthy choice recommendations (i.e., *trans* fat) was not attainable because of a lack of data on *trans* fat values of Canadian foods in the CNF (20). Each of the 19 components had a maximum score of 1.0; therefore, the maximum possible 2015 DGAI score was 19 points. The scoring scheme proposed by Imamura et al. (10) in 2009 was adopted in this research so that, instead of discrete scores of 0, 0.5, or 1 for each DGAI component, individuals were given a continuous score from 0 (total nonadherence) to 1 (complete adherence) that was proportional to their intakes. The use of this method was important because dichotomized scoring may conceal the true variability in dietary intakes and diminish the score range. More details regarding the calculation of the DGAI has been published previously (8, 10). An example on the basis of the 2000-kcal Food Pattern is presented in the **Supplemental Table 1**, which provides full details of the scoring scheme for the 2015 DGAI.

Food intake subscore

To calculate the food intake subscore, an individual's estimated energy requirement (EER) was first calculated with the use Institute of Medicine (IOM) factorial equations on the basis of the participant's measured height, weight, physical activity level (PAL; sedentary, low active, moderately active, or highly active), age, and sex (23). On the basis of the calculated EERs of subjects, which were rounded to the nearest 200 kcal, individuals were assigned to one of the corresponding USDA Food Patterns, which includes recommendations for 5 vegetable subgroups (dark green vegetables, red or orange vegetables, other vegetables, starchy vegetables, and legumes), fruit, variety of fruit and vegetables, grains, meat and beans, dairy, and added sugar. For each of these 11 food intake recommendations, individuals were scored proportionally from 0 to 1, with 0 representing total nonadherence and 1 reflecting total adherence to the recommended food intakes. Zero intakes of the food groups that were recommended in the 2015 DGA also received a score of 0 (10). The total sum of 11 scores was defined as the food intake subscore and reflected adherence to energy-specific USDA Food Pattern recommendations.

Legumes were counted toward the meat and beans group if participants needed to meet the recommended meat and beans score (i.e., as a lean-meat alternative) (8). The legume servings that were not needed to attain the recommended meat and beans servings were counted toward the legumes recommendations to avoid penalizing participants for the overconsumption of the meat group (8). The variety component gave credit to individuals who ate a variety of fruit and vegetables even if they did not meet the serving recommendations for each of the 6 vegetable and fruit components. The variety score was calculated by summing the scores of all 6 vegetable and fruit components.

Starchy vegetables, grains, meat, and dairy were considered energy-dense because the energy per serving of these foods was, on average, >50 kcal on the basis of the distribution of values for the different food groups (8). A penalty was imposed for the overconsumption of these 4 food groups by reducing the component score proportional to the amount of overconsumption up to intakes 1.25-times higher than recommended intake (10). Participants were penalized by a maximum 0.5 points for overconsumption amounts that were ≥1.25 times the recommendations (truncation) (10). For example, an individual who requires 2000 kcal is recommended to consume 3 cups dairy/d to receive the full 1.0 score for this food group (Supplemental Table 1). If the individual consumed 3.5 cups/d, a penalty of 0.17 points (overconsumption of 0.5 cups divided by the recommended 3 cups) was imposed, which left the subject with a score of 0.83 score (1.0 − 0.17) for dairy. However, if the individual consumed any amount of dairy >3.75 cups/d (1.25 times higher than the recommended 3 cups), the subject would be penalized by only a maximum of 0.5 points (1 − 0.5).

Healthy choice subscore

The 8 components of the healthy-choice subscore measured compliance to nutrient-intake recommendations on the basis of predetermined cutoffs regardless of a participant's EER. The following components were assessed to calculate the healthy choice subscore: the percentage of whole grains, fiber intake, 4 recommendations related to fat (total fat, saturated fat, cholesterol, and low-fat products), sodium intake, and alcohol consumption. Adherence to each of the components was scored proportionally by a value that ranged from 0 to 1 with components such as fat, sodium, and alcohol being reverse coded (higher intakes received lower scores within a recommended threshold).

Identification of implausible reporters

Previously, our group showed a widespread prevalence of misreporting in CCHS 2.2 participants (24). In this research, each participant was classified as an underreporter, plausible reporter, or overreporter according to a comparison of the individual's reported EI and calculated EER as described by our group previously (24). Because the IOM factorial equations used in this research require an individual's PAL (ratio of total energy expenditure to basal energy expenditure), the metabolic equivalent (kcal · kg^{-1} · d^{-1}; intensity of an activity compared with the resting metabolic rate) values available in the CCHS 2.2 were converted with the use of the IOM method (23). The method of McCrory et al. (25) [and its updated versions (26, 27)] for 4 different PALs was used to directly compare EIs and EERs with the use of cutoffs for their agreements on the basis of error-propagation calculations (25). All CIs were constructed in the log scale, and cutoffs were exponentiated to account for the skewed EI distribution in the CCHS 2.2 (24, 28). On the basis of our data set, participants whose EIs were <70% of their EERs were categorized as underreporters, and participants with EIs >142% of their EERs were classified as overreporters (±1 SD). Equations that were used for these calculations have been published previously (24–26, 28).

Statistical analyses

All analyses were conducted with the use of SAS software (version 9.4; SAS Institute Inc.), and a 2-tailed $P < 0.05$ was used to define statistical significance. To account for the CCHS 2.2 complex multistage-sampling framework, a variance estimation was performed with the use of the bootstrap-balanced repeated-replication technique (29). Briefly, a replicate weight was generated by randomly selecting a sample (with replacement) from the original sample and applying all of the adjustments to the selected sample. This exercise was repeated 500 times to develop 500 sample survey weights that were used for estimating the variance. To ensure a nationally representative sample, all analyses were weighted with the use of the specific sample survey weight that was calculated by Statistics Canada. Survey weighting is an adjustment technique that considers the complex sampling design and nonresponse bias of national surveys to ensure that final estimates are representative of the target population (16).

The population distributions of the total 2015 DGAI score and the food intake and healthy choice subscores were examined. The

2015 DGAI was distributed normally and was divided into quartile categories on the basis of the population distribution (quartile 1: 2.34–7.41; quartile 2: 7.42–8.82; quartile 3: 8.83–10.29; and quartile 4: 10.30–15.60) as was consistent with previous studies (8–10, 30). Covariate-adjusted associations between the 2015 DGAI score and continuous and categorical variables were determined with the use of a weighted multivariable linear regression and the least-square means, respectively. The P value for linear trend across the quartiles of the 2015 DGAI was calculated with the use of the DGAI variable that was entered as continuous. The P-trend represented the P value that was related to the linear regression coefficient (continuous dependent variables) (PROC SURVEYREG; SAS version 9.4) or the logistic regression coefficient (categorical dependent variable) (PROC SURVEYLOGISTIC; SAS version 9.4) in relation to the 2015 DGAI score.

Validity and reliability of the 2015 DGAI

Construct validity. In the first step, the concurrent-criterion validity and face validity were evaluated to test whether the 2015 DGAI could distinguish between population subgroups with known differences in dietary habits. Because previous studies have consistently shown that women, older adults, and nonsmokers have better-quality diets, we assessed the ability of the 2015 DGAI to identify the diet-quality differences of these groups with the use of weighted ANCOVA that was adjusted for age and sex (sex was adjusted only for age, and age was adjusted only for sex) (**Supplemental Table 2**). The face validity of the 2015 DGAI was also examined by evaluating whether it was related to the participants' characteristics and nutrient intakes in the expected direction on the basis of previous knowledge (31, 32). The weighted ANCOVA was used to compare sociodemographic, lifestyle, and dietary characteristics of participants across the quartile categories of the 2015 DGAI with adjustment for age, sex, and EI (for food groups only) (**Tables 1–3**). All analyses that pertained to nutrient intakes were reported as either the nutrient density (per 1000 kcal) (33) or as the percentage of energy to control for confounding and reduce extraneous measurement error and variability (34).

In the second step, to ensure that the 2015 DGAI could evaluate the diet quality of Canadians independent of their diet quantity (EIs), weighted Pearson correlation coefficients of the total 2015 DGAI score and its components with EIs were assessed (**Table 4**). Because food and nutrient intakes are positively correlated with EIs, individuals with higher EIs are more likely to receive higher diet-quality scores unless the index is uncoupled from EIs. This relation indicates that individuals should not receive higher diet-quality scores solely because they consume higher energy and, hence, meet the minimum dietary intake requirements for food groups and nutrients (35). Low correlations of diet-quality scores and EIs would reflect the independence of diet-quality scores from diet quantity.

In the third step, weighted principal component analysis (PCA) (PROC PRINCOMP; SAS version 9.4) was applied to the data to examine the underlying structure of the 2015 DGAI and to assess the number of dimensions accounting for the systematic variations in the data (**Supplemental Figure 1**). The PCA determined the correlations between index items and identified the number of underling independent dimensions within the index.

Reliability. The relations between individual index items (intercomponent) were assessed with the use of a weighted Pearson correlation analysis (Table 4). To determine the components with the most influence on the total score, the correlations of each component with the total score (minus that component score) was examined. The internal consistency of the 2015 DGAI was assessed by using Cronbach's coefficient α. Nunnally and Bernstein (36) have indicated that reliability coefficients >0.7 are acceptable for group-level comparisons, which was the level used in this study.

Adherence to the 2015 DGAI and risk of obesity

To examine the relation between adherence to the 2015 DGAI and risk of overweight or obesity, a multinomial logistic regression–generalized logit model (PROC SURVEYLOGISTIC; SAS version 9.4) was conducted with the use of a classification variable that indicated overweight and obesity as outcomes of interest and quartiles of the 2015 DGAI as exposure measures. The linearity assumption of the relation between the 2015 DGAI score and BMI in its continuous form was closely examined with the use of a weighted PROC LOESS statement (SAS version 9.4). Quartile 4 was chosen a priori as the reference category in all regression analyses because we hypothesized that our outcome of interest (obesity) would be higher in the lowest quartile of the 2015 DGAI score than in the highest quartile. Potential confounders were selected from the literature and were further examined in a weighted backward regression model. Covariates with the least influence on the information criteria and regression coefficient were excluded. Potential confounders were tested in the following 4 successive models: model 1 (basic model) was adjusted for age and sex only; model 2 was adjusted as for model 1 and for the misreporting status (underreporting, plausible reporting, or overreporting); model 3 was adjusted as for model 2 and for EI and PAL (inactive, moderately active, or active); and model 4 was adjusted as for model 3 variables and for smoking status (daily, occasional, former, or never).

To compare the predictive and discriminative value of different statistical models evaluating 2015 DGAI adherence and obesity risk, the area under the receiver operating curve (AUC) was used (c-statistic). The AUC appraised the ability of the 2015 DGAI score (in its continuous form) to accurately classify obese and nonobese subjects (37). Covariate-adjusted models (as previously detailed) were compared for statistical differences according to the recommendation of Janes et al. (38). Model-selection results were consistent with Akaike information criterion and Bayesian information criterion results.

Finally, regression analysis models were stratified to investigate the association of the 2015 DGAI and the risk of obesity with and without $\geq$1 chronic disease (e.g., diabetes, hypertension, heart disease, or cancer), referred to as unhealthy and healthy obese, respectively, as well as the risk of having $\geq$1 chronic disease without being obese. There have been suggestions that there is a subgroup within the obese population who lack the clustering of metabolic risk factors and, therefore, are "metabolically healthy" but obese (39, 40). The definition of a metabolically unhealthy individual in this research was on the basis of self-reported medical diagnosis of any of the chronic diseases in the national survey. The presence of all chronic diseases was pooled as consistent with previous research (41) because the 2015 DGA is also aimed at reducing the overall risk of chronic diseases.

TABLE 1
Weighted sociodemographic and lifestyle characteristics by quartile category of the 2015 DGAI in Canadian adults (≥18 y old) (n = 11,748)[1]

	2015 DGAI quartile category				
	1 (unhealthy)	2	3	4 (healthiest)	*P*-trend
DGAI range	2.34–7.41	7.42–8.82	8.83–10.29	10.30–15.60	—
DGAI score[2,3]	6.49	8.14	9.51	11.29	—
Food intake subscore[2,4]	2.7	3.38	4.16	5.29	—
Healthy choice subscore[2,5]	3.51	4.8	5.33	6.2	—
Women, %	37.7 ± 3.4	46.56 ± 3.23	54.4 ± 2.33	61.95 ± 2.86	<0.0001
Age, y	41.87 ± 0.44	44.08 ± 0.51	47.21 ± 0.53	51.19 ± 0.65	<0.0001
BMI, kg/m^2	28.07 ± 0.21	27.84 ± 0.22	27.27 ± 0.24	26.57 ± 0.21	<0.0001
Obesity, %	27.6 ± 1.61	27.46 ± 1.38	23.39 ± 1.37	20.95 ± 1.23	<0.0001
Obese with ≥1 chronic disease, %	17.16 ± 0.01	16.67 ± 0.01	13.07 ± 0.01	10.42 ± 0.01	<0.0001
Low-active participants, %	64.58 ± 2.04	58.08 ± 1.80	56.72 ± 2.04	51.68 ± 2.03	<0.0001
Having ≥1 chronic disease, %	52.3 ± 2.23	51.86 ± 2.46	45.66 ± 2.15	43.27 ± 2.47	0.0022
Current daily smokers, %	32.57 ± 1.66	22.15 ± 1.33	16.49 ± 1.00	13.29 ± 0.95	<0.0001
Multivitamin users, %	39.37 ± 2.05	43.25 ± 1.99	46.5 ± 1.99	47.27 ± 1.97	0.0069
Drank alcohol in the past 12 mo, %	87.03 ± 1.05	81.16 ± 1.54	79.71 ± 1.62	77.74 ± 1.90	<0.0001
Highest household education, %					<0.0001
Less than secondary school graduation	14.03 ± 1.14	12.13 ± 0.89	10.27 ± 0.73	7.72 ± 0.80	
Postsecondary education	62.7 ± 1.87	66.52 ± 1.94	70.55 ± 1.67	76.62 ± 1.50	
Highest respondent education, %					<0.0001
Less than secondary school graduation	24.97 ± 1.57	21.06 ± 1.32	19.22 ± 1.03	16.23 ± 1.22	
Postsecondary education	42.86 ± 1.93	48.34 ± 1.93	51.2 ± 1.74	56.31 ± 1.93	
Married, %	53.86 ± 0.02	56.64 ± 0.02	59.83 ± 0.02	62.62 ± 0.02	<0.0001
Single or never married, %	20.09 ± 0.01	18.34 ± 0.01	16.46 ± 0.01	14.9 ± 0.01	<0.0001
Immigrant,[6] %	16.76 ± 1.57	24.32 ± 2.14	26.44 ± 2.24	30.96 ± 3.73	<0.0001
Aboriginal, %	1.78 ± 0.28	1.51 ± 0.34	0.73 ± 0.17	0.78 ± 0.22	
Caucasian, %	92.28 ± 0.88	86.71 ± 1.67	86.99 ± 1.33	77.92 ± 2.82	<0.0001
Vegetables or fruit consumed <5 times/d, %	82.8 ± 1.30	74.14 ± 1.83	62.54 ± 1.97	51.53 ± 2.17	<0.0001
Excellent self-perceived health, %	17.54 ± 1.17	18.65 ± 1.35	22.26 ± 1.25	23.92 ± 1.40	<0.0001
Low stress level, %	35.29 ± 1.85	36.64 ± 1.92	35.04 ± 1.81	40.58 ± 1.93	0.0768
Highest-income group, %	36.49 ± 2.51	38.61 ± 2.32	37.03 ± 2.18	38.04 ± 1.97	0.6674
Urban residents, %	79.48 ± 1.40	79.32 ± 1.78	82.29 ± 1.46	84.06 ± 1.52	0.0047
Breakfast skippers, %	14.78 ± 1.67	8.75 ± 0.91	5.94 ± 0.78	5.12 ± 0.83	<0.0001

[1] All values are weighted means or percentages with bootstrapped variances (determined with the use of the balanced repeated-replication technique) ± SEs unless otherwise indicated. Covariate-adjusted associations between the 2015 DGAI score and continuous and categorical variables were determined with the use of a weighted multivariable linear regression and least-squares means, respectively. Values were adjusted for age and sex unless otherwise noted. Age was adjusted for sex only, and sex was adjusted for age only. *P*-trend was estimated with the use of the 2015 DGAI in its continuous form and represents the *P* value associated with the linear regression coefficient for continuous variables and the logistic regression coefficient for categorical variables. DGAI, Dietary Guidelines for Americans Adherence Index.

[2] Values are medians.

[3] Possible scores for the 2015 DGAI ranged from 0 to 19 with higher scores indicating more healthful and varied dietary patterns.

[4] Scores ranged from 0 to 11 possible points and are evaluated on the basis of energy level

[5] Scores ranged from 0 to 8 possible points and are evaluated on the same energy level for all participants.

[6] Immigrant status was defined by Statistics Canada in response to the following question: "In what year did you first come to Canada to live?" Possible responses were *1*) year: immigrant flag; *2*) not applicable: nonimmigrant; or *3*) do not know, refused to say, or not stated: not stated. Note that this question was asked of respondents who indicated that "they were not Canadian citizen by birth." Participants also answered the following question: "In what country were you born?" A derived variable was created on the basis of collective responses to these 3 questions that indicated immigrant status.

RESULTS

Validity and reliability of the 2015 DGAI

Construct validity

The distribution of the 2015 DGAI score followed a normal distribution and was wide enough to detect meaningful differences (**Figure 1**). The mean ± SE 2015 DGAI score and its 2 subscores (food intake and healthy choice) were 8.82 ± 0.05, 3.92 ± 0.04, and 4.90 ± 0.03, respectively, which indicates that the Canadian population was adherent to <50% of the 2015 DGA recommendations. The face validity of the 2015 DGAI was confirmed because the total DGAI score was associated, as expected, with several socioeconomic and lifestyle characteristics (Table 1). Participants in the highest DGAI quartile (healthiest diet quality) compared with those in the lowest quartile category were more likely to be women (61.95% compared with 37.7%, respectively; *P*-trend < 0.0001), older (51.19 compared with 41.87 y, respectively; *P*-trend < 0.0001), multivitamin-supplement users (47.27% compared with 39.37%, respectively; *P*-trend = 0.0069), married (62.62% compared with 53.86%, respectively; *P*-trend < 0.0001), and urban residents (84.06% compared with 79.48%, respectively; *P*-trend = 0.0047) with higher educational attainment (56.31% compared with 42.86%, respectively; *P*-trend < 0.0001). In addition, participants

TABLE 2
Weighted mean daily intakes of macronutrients and micronutrients reported as percentages of energy or per 1000 kcal (nutrient density) (33) by quartile category of the 2015 DGAI in Canadian adults (≥18 y old) (n = 11,748)[1]

	Model	2015 DGAI quartile category: 1 (unhealthy)	2	3	4 (healthiest)	*P*-trend
DGAI range[2]	—	2.34–7.41	7.42–8.82	8.83–10.29	10.30–15.60	—
Energy intake, kcal/d	a	2206 ± 54	2074 ± 68	2058 ± 34	2029 ± 35	0.0079
	b	2492 ± 26	2439 ± 32	2432 ± 24	2403 ± 22	0.0182
Carbohydrate, % of energy	a	43.35 ± 0.45	48.53 ± 0.46	50.76 ± 0.41	53.25 ± 0.38	<0.0001
	b	43.11 ± 0.46	48.17 ± 0.50	50.4 ± 0.45	52.91 ± 0.44	<0.0001
MUFAs, % of energy	a	14.42 ± 0.18	12.88 ± 0.23	12.06 ± 0.16	11.17 ± 0.18	<0.0001
	b	14.53 ± 0.19	13.08 ± 0.20	12.25 ± 0.18	11.34 ± 0.20	<0.0001
PUFAs, % of energy	a	5.6 ± 0.09	5.64 ± 0.12	5.73 ± 0.11	5.63 ± 0.11	0.8299
	b	5.67 ± 0.10	5.74 ± 0.11	5.83 ± 0.11	5.72 ± 0.12	0.7165
Linoleic acid, % of energy	a	4.41 ± 0.08	4.55 ± 0.09	4.57 ± 0.10	4.46 ± 0.09	0.4618
	b	4.46 ± 0.09	4.64 ± 0.10	4.66 ± 0.10	4.54 ± 0.10	0.2783
Linolenic acid, % of energy	a	0.8 ± 0.02	0.8 ± 0.03	0.83 ± 0.02	0.81 ± 0.03	0.8609
	b	0.81 ± 0.02	0.81 ± 0.03	0.84 ± 0.02	0.82 ± 0.03	0.8318
Protein, % of energy	a	15.52 ± 0.25	15.95 ± 0.29	16.78 ± 0.27	17.36 ± 0.22	<0.0001
	b	15.56 ± 0.25	15.91 ± 0.29	16.77 ± 0.28	17.38 ± 0.23	<0.0001
Alcohol, % of energy	a	4.64 ± 0.31	3.39 ± 0.31	2.32 ± 0.18	1.56 ± 0.14	<0.0001
	b	4.64 ± 0.31	3.42 ± 0.36	2.34 ± 0.21	1.57 ± 0.18	<0.0001
Cholesterol density, mg/1000 kcal	a	174.58 ± 4.85	146.81 ± 5.58	129.48 ± 4.01	108.68 ± 2.92	<0.0001
	b	173.97 ± 4.80	145.13 ± 5.43	128.09 ± 4.09	107.52 ± 3.69	<0.0001
Calcium density, mg/1000 kcal	a	405.39 ± 6.91	402.13 ± 7.69	438.06 ± 8.34	453.49 ± 8.41	<0.0001
	b	400.18 ± 7.19	394.94 ± 8.13	430.88 ± 8.78	446.44 ± 8.62	<0.0001
Vitamin A density in retinol-activity equivalents, μg/1000 kcal	a	286.18 ± 10.12	310.1 ± 10.55	412.73 ± 36.34	457.95 ± 15.81	<0.0001
	b	284.47 ± 9.80	305.61 ± 11.20	408.97 ± 33.27	454.8 ± 15.45	<0.0001
Vitamin D density, μg/1000 kcal	a	2.5 ± 0.10	2.67 ± 0.13	2.87 ± 0.11	3.3 ± 0.18	0.0004
	b	2.56 ± 0.13	2.74 ± 0.17	2.95 ± 0.13	3.38 ± 0.22	0.0003
Vitamin C density, mg/1000 kcal	a	38.91 ± 2.28	57.34 ± 1.92	73.64 ± 2.22	90.16 ± 2.02	<0.0001
	b	37.76 ± 2.14	55.41 ± 1.93	71.83 ± 2.12	88.47 ± 1.95	<0.0001
Sodium density, g/1000 kcal	a	1652.58 ± 41.19	1520.73 ± 23.85	1566.32 ± 23.27	1458.16 ± 32.01	0.0114
	b	1647.19 ± 42.22	1504.15 ± 29.44	1552.85 ± 24.56	1447.28 ± 30.88	0.0061
Thiamin density, mg/1000 kcal	a	0.72 ± 0.01	0.84 ± 0.01	0.91 ± 0.01	0.96 ± 0.02	<0.0001
	b	0.72 ± 0.01	0.83 ± 0.01	0.9 ± 0.014	0.95 ± 0.02	<0.0001
Riboflavin density, mg/1000 kcal	a	0.9 ± 0.01	0.93 ± 0.01	0.99 ± 0.02	1.01 ± 0.02	<0.0001
	b	0.89 ± 0.01	0.91 ± 0.01	0.98 ± 0.02	1 ± 0.02	<0.0001
Niacin density in niacin equivalents, mg/1000 kcal	a	17.97 ± 0.38	18.68 ± 0.27	20.51 ± 0.35	21.1 ± 0.32	<0.0001
	b	17.99 ± 0.38	18.59 ± 0.29	20.46 ± 0.34	21.08 ± 0.32	<0.0001
Vitamin B-6 density, mg/1000 kcal	a	0.7 ± 0.01	0.86 ± 0.02	1.02 ± 0.02	1.17 ± 0.02	<0.0001
	b	0.7 ± 0.01	0.85 ± 0.02	1.01 ± 0.02	1.16 ± 0.02	<0.0001
Vitamin B-12 density, μg/1000 kcal	a	2.14 ± 0.09	2.04 ± 0.09	2.31 ± 0.16	2.2 ± 0.13	0.5109
	b	2.16 ± 0.09	2.05 ± 0.09	2.32 ± 0.17	2.22 ± 0.14	0.4901
Naturally occurring folate density,[3] μg/1000 kcal	a	89.6 ± 1.96	108.29 ± 2.65	134.56 ± 3.37	150.79 ± 4.04	<0.0001
	b	88.33 ± 1.94	105.77 ± 2.20	132.3 ± 3.25	148.77 ± 3.99	<0.0001
Folacin density from food sources,[4] μg/1000 kcal	a	143.12 ± 2.49	170.72 ± 3.44	199.14 ± 3.47	209.63 ± 3.93	<0.0001
	b	142 ± 2.43	168.42 ± 3.06	197.1 ± 3.42	207.83 ± 4.17	<0.0001
Phosphorus density, mg/1000 kcal	a	601.19 ± 6.63	627.31 ± 7.43	684.48 ± 8.23	732.18 ± 7.97	<0.0001
	b	601.52 ± 6.92	624.79 ± 8.00	682.97 ± 8.41	731.46 ± 8.50	<0.0001
Magnesium density, mg/1000 kcal	a	135.61 ± 3.98	152.7 ± 1.83	178.19 ± 2.98	201.81 ± 2.32	<0.0001
	b	134.73 ± 3.80	150.26 ± 1.67	176.17 ± 2.96	200.13 ± 2.19	<0.0001
Iron density, mg/1000 kcal	a	6.11 ± 0.08	6.84 ± 0.09	7.42 ± 0.10	7.81 ± 0.10	<0.0001
	b	6.06 ± 0.08	6.76 ± 0.08	7.34 ± 0.10	7.75 ± 0.10	<0.0001
Zinc density, mg/1000 kcal	a	5.16 ± 0.09	5.34 ± 0.12	5.66 ± 0.08	6.06 ± 0.07	<0.0001
	b	5.16 ± 0.10	5.31 ± 0.12	5.64 ± 0.08	6.04 ± 0.08	<0.0001
Potassium density, mg/1000 kcal	a	1238.73 ± 17.28	1465.95 ± 20.81	1694.55 ± 20.38	1926.54 ± 24.53	<0.0001
	b	1231.92 ± 16.64	1444.58 ± 16.32	1677.24 ± 20.06	1912.61 ± 22.84	<0.0001
Caffeine density, mg/1000 kcal	a	158.23 ± 9.92	138.55 ± 7.64	125.48 ± 5.01	105.96 ± 4.60	<0.0001
	b	154.26 ± 9.73	130.07 ± 6.04	118.02 ± 5.14	99.41 ± 4.44	<0.0001

(Continued)

TABLE 2 (*Continued*)

	Model	2015 DGAI quartile category 1 (unhealthy)	2	3	4 (healthiest)	*P*-trend
Moisture density,[5] g/1000 kcal	a	1423.37 ± 45.27	1487.35 ± 40.16	1534.59 ± 32.27	1632.65 ± 35.79	0.0067
	b	1386.36 ± 39.50	1409.28 ± 34.45	1465.72 ± 27.84	1571.96 ± 30.76	0.0014
Glycemic index density, per 1000 kcal	a	34.46 ± 1.97	33 ± 1.11	30.83 ± 0.56	28.71 ± 0.57	0.0031
	b	33.24 ± 1.90	30.59 ± 0.48	28.67 ± 0.38	26.78 ± 0.39	<0.0001
Energy density, per 1000 kcal	a	1.41 ± 0.10	1.14 ± 0.04	0.96 ± 0.02	0.77 ± 0.02	<0.0001
	b	1.37 ± 0.11	1.06 ± 0.02	0.88 ± 0.02	0.7 ± 0.02	<0.0001

[1] All values are weighted means with bootstrapped variances (determined with the use of the balanced repeated-replication technique) ± SEs unless otherwise indicated. Covariate-adjusted associations were determined with the use of a weighted multivariable linear regression. Values were adjusted for age and sex (model a) plus misreporting status (model b). *P*-trend was estimated with the use of the 2015 DGAI in its continuous form and represents the *P* value associated with the linear regression coefficient. DGAI, Dietary Guidelines for Americans Adherence Index.

[2] Possible scores for the 2015 DGAI ranged from 0 to 19 with higher scores indicating more healthful and varied dietary patterns.

[3] Naturally occurring folate included various forms of folate that are naturally present in food.

[4] Sum of quantities of naturally occurring folate in addition to folic acid without consideration of their differing bioavailabilities.

[5] Water content in foods is abundant in fruit and vegetables such as tomatoes, romaine lettuce, and grapefruit.

in the highest DGAI quartile had lower BMIs (26.57% compared with 28.07, respectively; *P*-trend < 0.0001) and were less likely to drink alcohol (77.74% compared with 87.03%, respectively; *P*-trend < 0.0001), to be low-active subjects (51.68 % compared with 64.58%, respectively; *P*-trend < 0.0001), to be daily smokers (13.29% compared with 32.57%, respectively; *P*-trend < 0.0001), and to skip breakfast (5.12% compared with 14.78%, respectively; *P*-trend < 0.0001).

Concurrent criterion validity tests revealed that the mean 2015 DGAI score was significantly higher in women than in men (9.28 ± 0.05 compared with 8.56 ± 0.06, respectively) and in older adults than in younger adults in the age- and sex-adjusted models (*P*-trend < 0.0001) (Supplemental Table 2). Similarly, the mean 2015 DGAI score was higher in the never-smoker group (9.28 ± 0.05) than in occasional, former, and daily smokers (8.11 ± 0.08) (*P*-trend < 0.0001).

After adjustment for age and sex, all nutrients that were examined (except for the percentage of energy from PUFAs, linoleic acid, linolenic acid, and vitamin B-12 density) were significantly associated with the 2015 DGAI score (Table 2). Specifically, there was a significant positive trend for the association of the DGAI score and the percentage of energy from carbohydrates and densities of protein, calcium, vitamin A, vitamin D, vitamin C, thiamin, riboflavin, niacin, vitamin B-6, folate, folacin, phosphorus, magnesium, iron, zinc and potassium. In contrast, EI and the percentages of energy from MUFAs and alcohol as well as cholesterol, sodium, caffeine, the glycemic index, and energy densities showed an inverse linear trend with the 2015 DGAI score (*P*-trend < 0.01). Similarly, when food intake and healthy choice subscores were examined, individuals in the highest quartile category of the 2015 DGAI had lower mean intakes of added sugars (percentage of energy), total fat (percentage of energy), saturated fat (percentage of energy), cholesterol (milligrams), sodium (milligrams), and alcohol (drink), whereas their intakes of fruit and vegetable subgroups were higher with significant linear trends (*P*-trend < 0.0001) (Table 3). Further adjustment for misreporting status did not have any effect on the direction and significance of any of these trends (Tables 2 and 3, model b).

Multidimensional radar plots were built to represent the percentage of compliers and intermediate compliers as well as underconsumers and overconsumers for each of the 2015 DGAI components (**Figure 2**). In Figure 2, each spoke of the radar plots shows an individual DGAI component, and each line color represents a different category of compliance. The largest outer circle represents 100% prevalence, and the smallest circle represents 0% prevalence. None of the participants adhered to all 2015 DGAI recommendations. Only 4.7%, 22%, 4.9%, 36.2%, and 7.7% of participants scored >0.9 (possible maximum score: 1.0 point) for each of the 5 vegetable-subgroup recommendations, including starchy vegetables, dark green vegetables, red and orange vegetables, other vegetables, and legumes, respectively. The low scores for meat and beans and grains were mainly caused by the overconsumption of these food groups rather than by underconsumption (Figure 2A). In addition, 60.5% and 43.46% of Canadians overconsumed added sugars and sodium, respectively.

To ensure that the total DGAI score measured diet quality independent of energy, the correlation of EI with the DGAI score was determined (Table 4). The total DGAI score had a negative correlation with EI ($r = -0.16$), and the correlation coefficients between each index component and energy were also small for all index components except for the sodium recommendation ($r = -0.61$).

To explore the dimensionality of the 2015 DGAI and the number of principal components to retain, the weighted PCA scree plot and the criterion of eigenvalues >1 were used. The scree-plot curve leveled off at around 5 dimension, which explained 45.58% of the total 2015 DGAI variation (Supplemental Figure 1). With the use of the criterion of eigenvalues >1, 8 principal components were retained, which explained 61.73% of the total variation in the 2015 DGAI score. These results confirmed the multidimensionality of the 2015 DGAI score and showed that none of the individual 2015 DGAI components accounted for the majority of variation in the key guidance that made up the total score.

Reliability

The standardized Cronbach's coefficient α for the 2015 DGAI components was 0.75 (unstandardized: 0.74), and it did not change significantly after the removal of a variable from the

TABLE 3
Weighted means of components used to calculate the total 2015 DGAI score presented across quartile categories of the DGAI in Canadian adults (≥18 y old) (n = 11,748)[1]

	Model	2015 DGAI quartile category: 1 (unhealthy)	2	3	4 (healthiest)	P-trend
DGAI range[2]	—	2.34–7.41	7.42–8.82	8.83–10.29	10.30–15.60	—
Food intake subscore	a	2.62 ± 0.04	3.40 ± 0.04	4.22 ± 0.03	5.41 ± 0.04	<0.0001
	b	2.61 ± 0.04	3.39 ± 0.04	4.20 ± 0.04	5.39 ± 0.04	<0.0001
Dark green vegetables, cups/wk	a	0.24 ± 0.08	0.76 ± 0.16	1.52 ± 0.11	3.06 ± 0.24	<0.0001
	b	0.27 ± 0.09	0.79 ± 0.22	1.55 ± 0.15	3.09 ± 0.32	<0.0001
Red and orange vegetables, cups/wk	a	0.32 ± 0.11	0.62 ± 0.07	1.04 ± 0.08	2.02 ± 0.13	<0.0001
	b	0.38 ± 0.09	0.68 ± 0.10	1.1 ± 0.12	2.09 ± 0.14	<0.0001
Legumes,[3] cups/wk	a	0.21 ± 0.10	0.46 ± 0.10	0.92 ± 0.15	1.36 ± 0.13	<0.0001
	b	0.11 ± 0.04	0.45 ± 0.14	0.92 ± 0.18	1.37 ± 0.19	<0.0001
Starchy vegetables, cups/wk	a	2.5 ± 0.18	3.12 ± 0.20	3.34 ± 0.17	3.75 ± 0.16	<0.0001
	b	2.38 ± 0.23	3 ± 0.21	3.23 ± 0.22	3.65 ± 0.21	<0.0001
Other vegetables, cup/wk	a	2.41 ± 0.24	3.69 ± 0.23	4.9 ± 0.21	7.32 ± 0.26	<0.0001
	b	2.66 ± 0.28	3.93 ± 0.31	5.16 ± 0.26	7.59 ± 0.33	<0.0001
Fruit, cups/d	a	0.42 ± 0.04	0.93 ± 0.07	1.25 ± 0.05	1.56 ± 0.06	<0.0001
	b	0.45 ± 0.05	0.96 ± 0.07	1.27 ± 0.06	1.59 ± 0.06	<0.0001
Variety of fruit and vegetables, components, n	a	0.89 ± 0.03	1.38 ± 0.03	1.96 ± 0.03	2.77 ± 0.03	<0.0001
	b	0.93 ± 0.03	1.41 ± 0.03	1.99 ± 0.03	2.8 ± 0.04	<0.0001
Grains, oz equivalents/d	a	5.27 ± 0.12	6.17 ± 0.13	6.27 ± 0.12	6.08 ± 0.12	<0.0001
	b	5.38 ± 0.16	6.28 ± 0.15	6.38 ± 0.18	6.18 ± 0.18	<0.0001
Meat and beans,[3] oz equivalents/d	a	5.56 ± 0.18	5.1 ± 0.17	5.36 ± 0.17	5.58 ± 0.15	0.1492
	b	5.56 ± 0.23	5.1 ± 0.23	5.37 ± 0.18	5.6 ± 0.22	0.1301
Dairy, cups/d	a	1.36 ± 0.07	1.34 ± 0.05	1.4 ± 0.05	1.5 ± 0.04	0.0769
	b	1.33 ± 0.08	1.31 ± 0.07	1.36 ± 0.07	1.47 ± 0.06	0.089
Added sugar,[4] % of energy	a	12.04 ± 0.37	10.47 ± 0.35	8.93 ± 0.28	7.44 ± 0.28	<0.0001
	b	11.81 ± 0.37	10.29 ± 0.36	8.7 ± 0.30	7.19 ± 0.29	<0.0001
Healthy choice subscore	a	3.67 ± 0.04	4.76 ± 0.03	5.31 ± 0.03	6.09 ± 0.03	<0.0001
	b	3.70 ± 0.04	4.79 ± 0.04	5.34 ± 0.03	6.09 ± 0.03	<0.0001
Whole grain, % of grains	a	8.52 ± 0.74	16.43 ± 1.03	20.57 ± 0.94	31.37 ± 1.32	<0.0001
	b	8.01 ± 0.83	15.93 ± 1.05	20.26 ± 0.99	31.27 ± 1.45	<0.0001
Dietary fiber density, g/1000 kcal	a	5.73 ± 0.11	7.82 ± 0.14	9.72 ± 0.25	12.13 ± 0.19	<0.0001
	b	5.72 ± 0.11	7.75 ± 0.13	9.67 ± 0.25	12.1 ± 0.19	<0.0001
Total fat, % of energy	a	36.49 ± 0.40	32.13 ± 0.41	30.14 ± 0.34	27.83 ± 0.30	<0.0001
	b	36.69 ± 0.40	32.5 ± 0.38	30.48 ± 0.37	28.14 ± 0.34	<0.0001
SFAs, % of energy	a	13.22 ± 0.22	10.46 ± 0.19	9.31 ± 0.12	8.09 ± 0.10	<0.0001
	b	13.25 ± 0.21	10.54 ± 0.18	9.37 ± 0.13	8.15 ± 0.11	<0.0001
Cholesterol intake, mg/d	a	362.54 ± 9.71	285.01 ± 9.09	257.22 ± 7.65	215.69 ± 6.07	<0.0001
	b	362.56 ± 11.06	285.03 ± 10.94	257.42 ± 8.89	216.06 ± 9.96	<0.0001
Low-fat dairy and meat products, %	a	31.05 ± 1.03	38.77 ± 0.94	46.21 ± 0.84	55.06 ± 0.99	<0.0001
	b	31.39 ± 1.21	39.08 ± 1.08	46.58 ± 0.91	55.46 ± 1.19	<0.0001
Sodium, mg/d	a	3221.9 ± 55.92	3043.71 ± 59.75	3095.58 ± 45.27	2897.94 ± 67.97	0.0145
	b	3207.96 ± 66.03	3030.12 ± 82.18	3083.87 ± 58.08	2888.63 ± 78.68	0.0148
Alcohol,[5] drinks/d	a	1.18 ± 0.08	0.85 ± 0.09	0.6 ± 0.05	0.41 ± 0.04	<0.0001
	b	1.13 ± 0.09	0.8 ± 0.12	0.55 ± 0.08	0.36 ± 0.07	<0.0001

[1] Estimates are weighted means with bootstrapped variances (determined with the use of the balanced repeated-replication technique) ± SEs unless otherwise indicated. Covariate-adjusted associations were determined with the use of a weighted multivariable linear regression. Values were adjusted for age, sex, and energy intake (model a) plus misreporting status (model b) unless otherwise noted. Added sugar (% of energy), dietary fiber density (g/1000 kcal), total fat (% of energy), and SFA (% of energy) were not adjusted for energy intakes because energy was already accounted for in their definitions. 1 cup = 237 mL (United States) and 0.946 cups in metric units; 1 oz = 28.35 g. P-trend was estimated with the use of the 2015 DGAI in its continuous form and represents the P value associated with the linear regression coefficient. DGAI, Dietary Guidelines for Americans Adherence Index.

[2] Possible scores for the 2015 DGAI ranged from 0 to 19 with higher scores indicating more healthful and varied dietary patterns.

[3] Legumes were assigned to the meat and bean group for individuals who needed to meet the 1-point criterion for the meat and beans group, and the extra servings were counted toward the vegetable group (legumes).

[4] Determined with the use of the method proposed by Brisbois et al. (21) to derive estimates of added sugars.

[5] 1 drink = 118 mL wine, 355 mL beer, or 45 mL distilled spirit.

constructs (data not shown). Correlations between the 2015 DGAI score and food intake (r = 0.73) and healthy choice (r = 0.71) subscores were high, whereas the subscores were not intercorrelated (r = 0.03) (Table 4). Correlation coefficients of the total 2015 DGAI score with individual component scores were all significant and positive, ranging from r = 0.10 for dairy and r = 0.11 for grain scores to r = 0.69 for the variety of fruit and vegetables and r = 0.64 for fiber-density scores. Similarly,

TABLE 4
Weighted correlations between total and component scores of the 2015 DGAI as well as energy intakes in Canadian adults (≥18 y old) (n = 11,748)[1]

Component	Starchy vegetables	Dark green vegetables	Red and orange vegetables	Other vegetables	Legumes	Fruit	Meat and beans	Dairy	Grains	Added sugar	Variety	Whole grain	Fiber density	Total fat	SFAs	Cholesterol	Low-fat dairy	Low-fat meat	Sodium	Alcohol	Food intake subscore	Healthy choice subscore	Total DGAI score
Starchy vegetables	1.00																						
Dark green vegetables	0.07*	1.00																					
Red and orange vegetables	0.06*	0.13*	1.00																				
Other vegetables	−0.02	0.31*	0.22*	1.00																			
Legumes	0.01	0.04*	0.06*	0.10*	1.00																		
Fruit	−0.03*	0.11*	0.06*	0.11*	0.06*	1.00																	
Meat and beans	0.10*	0.08*	0.05*	0.08*	0.1*	0.04*	1.00																
Dairy	0.01	0.03*	0.01	0.02*	0.01	0.10*	0.03*	1.00															
Grains	−0.03*	0.01	−0.05*	0.02*	0.00	0.05*	0.03*	0.08*	1.00														
Added sugar	−0.05*	0.04*	0.07*	0.09*	0.06*	−0.09*	0.02	−0.04*	−0.13*	1.00													
Variety	0.34*	0.63*	0.45*	0.64*	0.36*	0.48*	0.17*	0.06*	0.01	0.04*	1.00												
Whole grain	−0.02*	0.01	0.06*	−0.03*	0.06*	0.13*	0.01	0.04*	−0.01	0.03*	0.07*	1.00											
Fiber density	−0.02*	0.22*	0.18*	0.21*	0.09*	0.34*	−0.05*	−0.07*	0.06*	0.15*	0.36*	0.39*	1.00										
Total fat	0.02	0.07*	0.01	0.03*	−0.05*	0.14*	0.02*	0.01	0.12*	−0.13*	0.08*	0.03*	0.20*	1.00									
SFAs	0.00	0.06*	0.04*	0.04*	0.05*	0.16*	0.02	−0.23*	0.03*	−0.03*	0.13*	0.10*	0.32*	0.46*	1.00								
Cholesterol	−0.06*	−0.01	−0.04*	−0.06*	−0.08*	0.04*	−0.13*	−0.05*	0.03*	−0.05*	−0.06*	0.08*	0.26*	0.17*	0.25*	1.00							
Low-fat dairy	−0.02*	0.03*	0.04*	0.02*	0.01	0.08*	0.04*	0.21*	0.02*	0.03*	0.06*	0.12*	0.14*	0.09*	0.17*	0.09*	1.00						
Low-fat meat	0.01	0.08*	0.12*	0.05*	0.11*	0.09*	0.18*	−0.03*	0.03*	0.02	0.14*	0.03*	0.07*	0.05*	0.13*	−0.18*	0.06*	1.00					
Sodium	−0.06*	−0.02*	−0.03*	−0.20*	−0.14*	0.00	−0.16*	−0.24*	−0.20*	0.04*	−0.15*	0.06*	0.13*	0.08*	0.14*	0.29*	0.01	0.05*	1.00				
Alcohol	−0.01	−0.02*	0.03*	−0.04*	−0.03*	0.05*	−0.05*	0.01	0.04*	−0.11*	−0.01	0.04*	0.12*	−0.08*	−0.08*	0.11*	0.04*	0.02*	0.09*	1.00			
Food intake subscore	0.28*	0.57*	0.40*	0.59*	0.36*	0.40*	0.35*	0.26*	0.15*	0.33*	0.9*	0.08*	0.33*	0.06*	0.06*	−0.10*	0.11*	0.16*	−0.22*	−0.05*	1.00		
Healthy choice subscore	−0.04*	0.08*	0.07*	−0.03*	−0.03*	0.22*	−0.07*	−0.12*	0.01	−0.03*	0.09	0.45*	0.59*	0.48*	0.6*	0.58*	0.31*	0.18*	0.53*	0.34*	0.03	1.00	
Total DGAI score	0.17*	0.45*	0.33*	0.39*	0.23*	0.43*	0.20*	0.10*	0.11*	0.21*	0.69*	0.36*	0.64*	0.37*	0.45*	0.33*	0.29*	0.24*	0.21*	0.2*	0.73*	0.71*	1.00
Energy	0.14*	0.04*	0.04*	0.13*	0.19*	0.08*	0.19*	0.28*	0.18*	−0.13*	0.2*	−0.09*	−0.21*	−0.09*	−0.10*	−0.40*	−0.06*	−0.01	−0.61*	−0.20*	0.25*	−0.49*	−0.16*

[1] All values are weighted Pearson correlation coefficients. Possible scores for the 2015 DGAI ranged from 0 to 19 with higher scores indicating more healthful and varied dietary patterns. *Significant, $P < 0.05$. DGAI, Dietary Guidelines for Americans Adherence Index.

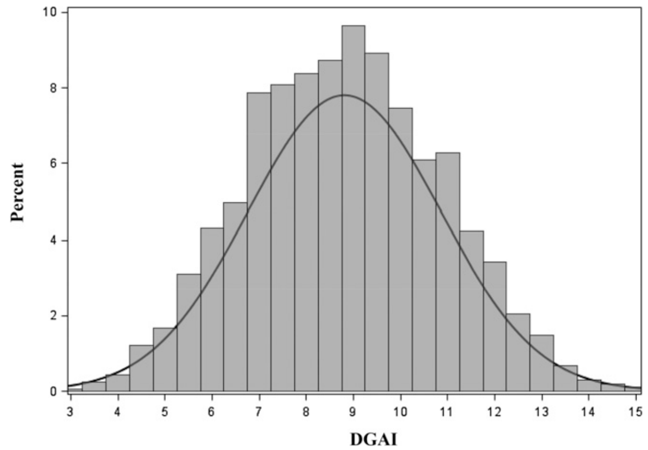

FIGURE 1 Weighted distribution of the 2015 DGAI in Canadian adults (≥18 y old) (n = 11,748). The 1% and 99% of distribution tails were trimmed according to Statistics Canada's data-release requirements. Possible scores for the 2015 DGAI ranged from 0 to 19, with higher scores indicating more healthful and varied dietary patterns. DGAI, Dietary Guidelines for Americans Adherence Index.

the food intake subscore was strongly correlated with the variety score (r = 0.90) and was most weakly correlated with the alcohol score (r = −0.05). The healthy choice subscore was most strongly correlated with the total saturated fat score (r = 0.60), whereas grains contributed the lowest correlation coefficient (r = 0.01).

Adherence to the 2015 DGAI and risk of obesity

Moving from the highest quartile of the 2015 DGAI score (healthiest, reference quartile) to the lowest (unhealthiest), the age- and sex-adjusted OR of obesity increased monotonically from 1.42 (95% CI: 1.1, 1.84) in quartile 3 to 1.81 (1.39, 2.36) in quartile 2 to 1.92 (1.5, 2.45) in quartile 1 (P-trend < 0.0001) (**Figure 3**). Further adjustment for the misreporting status (model 2) strengthened all of the associations across quartiles, with participants in quartile 1 compared with quartile 4 showing 2 times higher risk of obesity (P-trend < 0.0001). The direction and significance of the association persisted after mutual adjustment for all potential confounders including EI, PAL, and smoking status, although the magnitude was attenuated (models 3 and 4; P-trend < 0.0001). The AUC ranged from 0.57 in model 1 to 0.61 in model 2 to 0.66 in models 3 and 4, which confirmed the predictive accuracy of the 2015 DGAI score for discriminating between the obese and nonobese subjects in this study (**Supplemental Figure 2**).

Finally, participants were jointly classified by their weight and chronic disease status. A lack of adherence to the 2015 DGAI recommendations increased the OR of being unhealthy obese from 1.42 (95% CI: 1.02, 1.99) in quartile 3 to 2.08 (95% CI: 1.49, 2.9) in quartile 2 to 2.31 (95% CI: 1.65, 3.23) in the first quartile of the 2015 DGAI score (model 1) (P-trend < 0.0001) (**Figure 4**). Although the probability of being obese without having a chronic disease (healthy obese) (OR: 2.17; 95% CI: 1.4, 3.38; P-trend < 0.0001) and risk of having a chronic disease without obesity (OR: 1.41; 95% CI: 1.02, 1.94; P-trend = 0.0054] also increased in the lowest quartile of the 2015 DGAI score compared with in the highest quartile, the magnitude of these associations was slightly smaller. Further adjustment for misreporting status in model 2 slightly strengthened the associations. In the multivariate-adjusted model (model 4), a lack of adherence to the DGA guidance (quartile 1) was still positively associated with risk of being unhealthy obese (OR: 2.17; 95% CI: 1.53, 3.08), healthy obese (OR: 2.04; 95% CI: 1.30, 3.19), and unhealthy nonobese (OR: 1.37; 95% CI: 0.98, 1.93) compared with the highest quartile category (P-trend < 0.0001).

DISCUSSION

To our knowledge, this is the first examination of population compliance to the US Department of Health and Human Services/USDA 2015 DGA in relation to several dietary and chronic-disease risk factors. In addition, this is the first evaluation, to our knowledge, of dietary patterns of Canadians that used a multidimensional a priori dietary quality index (i.e., the DGAI), which is based on 12 different levels of energy requirement. Our results showed strong and consistent evidence of the validity and reliability of the 2015 DGAI for measuring the diet quality of Canadian adults. The face validity and concurrent criterion validity of the 2015 DGAI were confirmed through its robust association with various socioeconomic, lifestyle, and dietary characteristics in the expected direction. The 2015 DGAI score was higher in women, older individuals, and subjects who were physically active, nonsmokers, urban residents, leaner, and vitamin-supplement users. We also noted that because the total DGAI score simultaneously represents many diet quality aspects, intakes of several macronutrients and micronutrients that were not explicitly built into the index were also higher with closer adherence to the 2015 DGAI recommendations. However, none of the participants reported complete adherence to the 2015 DGA recommendations especially for energy-based recommendations of starchy vegetables, grains, meat, and dairy, which were overconsumed, as was also shown previously in Canadians (42, 43). The lack of compliance to the 2015 DGAI guidance in this study was associated with 2.31- and 2.17-times higher risks of obesity with and without an accompanying chronic disease and 1.41-times higher risk of having a chronic disease without obesity.

The 2015 DGAI score was able to uncouple the quantity and quality of food consumption because it was developed to ensure individuals would not receive higher scores solely by energy overconsumption (8). This aspect is in contrast with other indexes (e.g., the Alternative Healthy Eating Index, alternate Mediterranean diet, and Dietary Approaches to Stop Hypertension), which have shown positive associations with EIs (41, 44–46). This difference may be explained by the underlying scoring scheme of the DGAI, which is based on 12 levels of energy requirement with an overconsumption penalty as opposed to having absolute cutoff or the use of the density approach.

When individual component scores were investigated separately, none of them drove the associations, thereby confirming that components work synergistically to form the total index score (8–10, 30). The PCA results confirmed the multidimensionality of 2015 DGAI and showed no evidence of a single, systematic, underlying structure in the 19 components of the DGAI that could have explained much of the variation in the data. This finding is in line with research that has evaluated

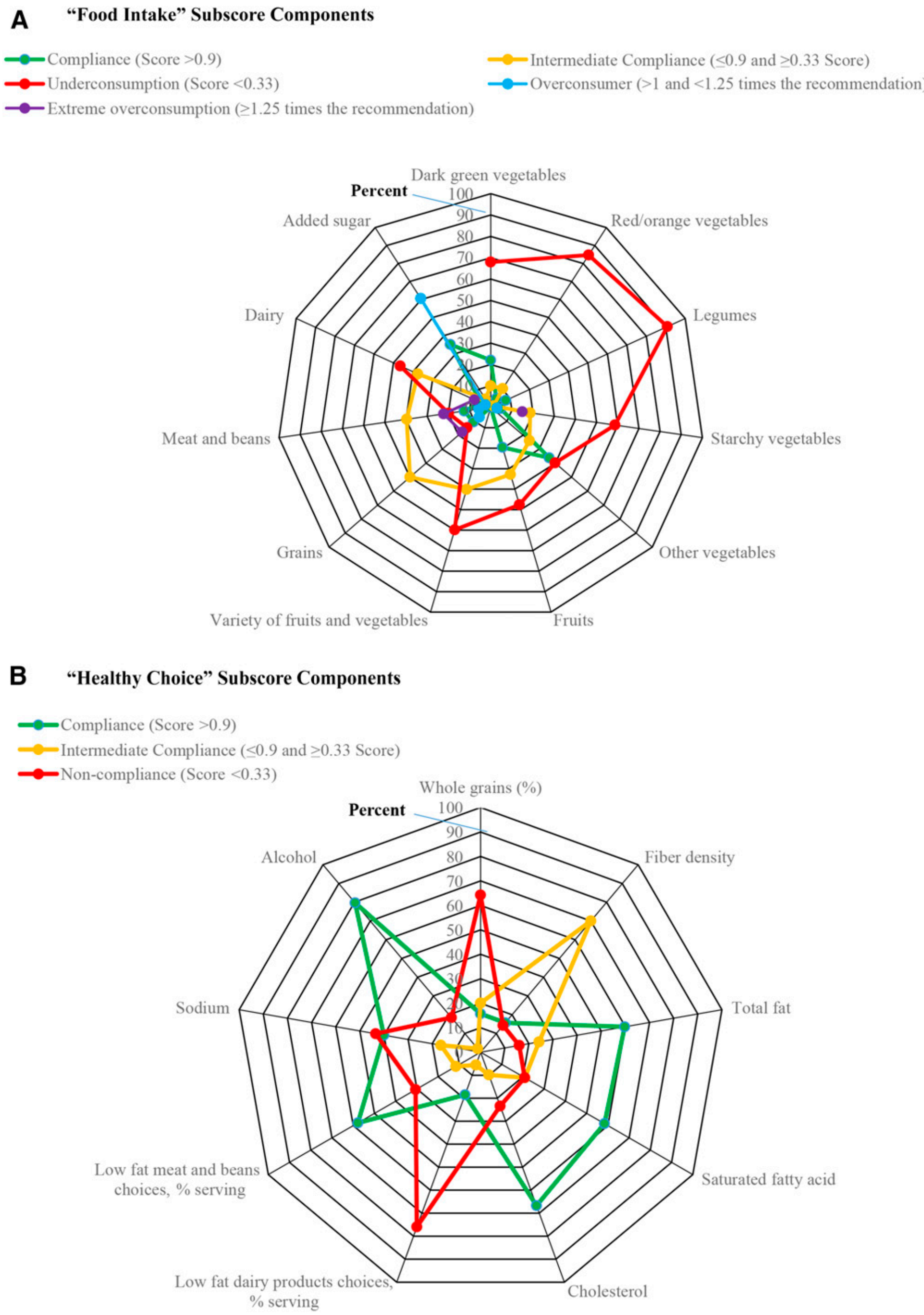

FIGURE 2 Weighted percentages of compliance (score >0.9), intermediate compliance (score ≤0.9 and ≥0.33), underconsumption (score <0.33), overconsumption (>1 and <1.25 times the recommendation), and extreme overconsumption (≥1.25 times the recommendation) for each of the components of the food intake subscore (A) and healthy choice subscore (B) of the 2015 DGAI in Canadian adults (≥18 y old) (n = 11,748). Each spoke of the radar plots shows an individual DGAI component, and each line color represents a different category of compliance. The largest outer circle represents 100% prevalence, and the smallest circle represents 0% prevalence. The color coding of different compliance groups facilitates the identification of food groups with the highest percentage of compliers, intermediate compliers, underconsumers, overconsumers, and extreme overconsumers for each of the 2015 DGAI components. Possible scores for the 2015 DGAI ranged from 0 to 19, with higher scores indicating more healthful and varied dietary patterns. All differences between compliance groups for the 2015 DGAI components were significant (P < 0.0001). The overconsumption penalty was calculated only for energy-dense food groups including starchy vegetables, grains, meat, and dairy. There is no underconsumer group defined for added sugars. DGAI, Dietary Guidelines for Americans Adherence Index.

the Healthy Eating Index (35) and suggests that each of the 19 components provide additional important and valuable information regarding the diet quality of Canadian adults in addition to the total sum score. The reliability (internal consistency) of the 2015 DGAI was also confirmed by a high Cronbach's α, which indicated that the overall score captured the construct of diet quality in Canadian adults with adequate confidence. The total variation in the 2015 DGAI score directly

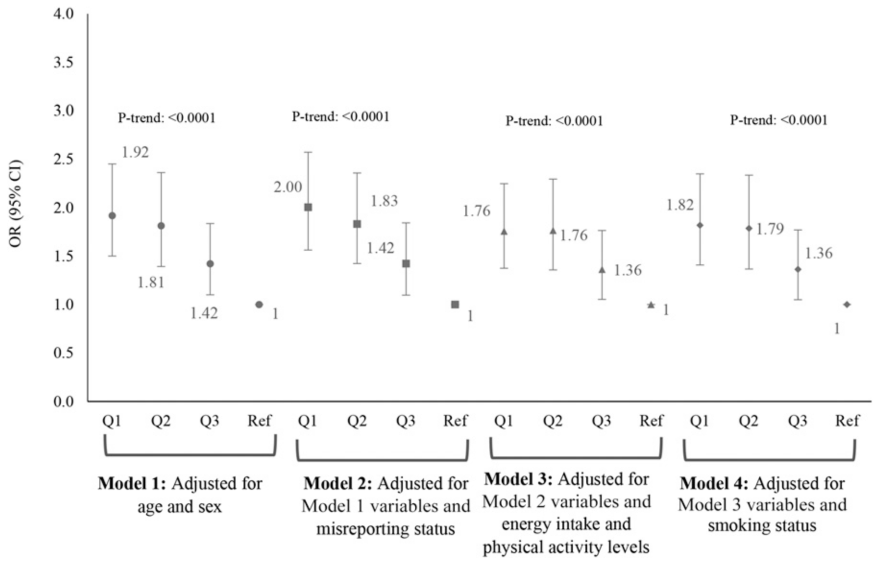

FIGURE 3 Weighted multivariate-adjusted ORs (95% CIs) for obesity risk [BMI (in kg/m^2) ≥30] across Q categories of the 2015 DGAI in Canadian adults (≥18 y old) (n = 11,748). Estimates were based on the multinomial logistic regression–generalized logit model. *P*-trend was based on the logistic regression coefficient for the 2015 DGAI as a continuous variable. DGAI, Dietary Guidelines for Americans Adherence Index; Q, quartile.

reflected the variation in individual components that had high correlations with the total score (i.e., the variety of fruit and vegetables and fiber density). Index items such as dairy and grains, which had the least correlation with the total 2015 DGAI score, similar to the 2010 Healthy Eating Index score (35), did not necessarily add variation to the total score but, rather, provided important independent information about diet quality (35).

The significant gains shown in obesity risk with each quartile of the 2015 DGAI score suggested that even small improvements in diet quality may have meaningful health benefits. The assessment of different subgroups within the obese and nonobese population is essential because recent studies have suggested that the “metabolically healthy” obese phenotype may not present the same range of metabolic disorders as the “metabolically unhealthy” obese does (47). In the current study, a lack of adherence to the 2015 DGAI recommendations was consistently associated with a higher risk of unhealthy obesity followed by healthy obesity and being unhealthy nonobese. Further adjustment for the misreporting bias slightly strengthened diet-disease relations in line with previous studies (24, 48). These results are consistent with those of previous research that have shown inverse associations between adherence to the DGA and risks of obesity, metabolic syndrome, insulin resistance, and coronary artery atherosclerosis (8–13, 30). A prospective cohort study in France compared how the 2005 DGAI, the Diet Quality Index-International, the French Guideline Score, the Mediterranean Diet Scale, the relative Mediterranean Diet Score, and the Mediterranean Style Dietary Pattern Score were associated with weight changes over 13 y of follow-up (49). Although scores for all indexes (except for the Mediterranean Style Dietary Pattern Score) were significantly associated with reduced risk of becoming obese after 13 y in men, adherence to the 2005 DGAI provided the highest benefit (49). The predictive validity of the DGAI was confirmed in another prospective study in which a 1-SD difference in the weighted DGAI score was associated with 0.049-mm less coronary artery narrowing over a 3-y period (10).

In our study, even subjects in the highest quartile category of the DGAI (healthiest) had substantial room for improvement (median DGAI score: 11.29 out of 19). Future research needs to examine the benefits that could be achieved by attaining more optimal dietary quality scores.

To our knowledge, this is the first and largest study to examine the validity and reliability of the 2015 DGAI and to evaluate the benefits of following the 2015 USDA Food Patterns in relation to risk of obesity with and without other chronic diseases. The use of the algorithm-based method of McCrory et al. (25) to account for the misreporting bias, the measured anthropometric measures, and the collection of comprehensive dietary and lifestyle data were important strengths of this research. To minimize floor and ceiling effects, we used a proportional scoring scheme (10) instead of the original DGAI dichotomous scoring system with fixed binary cutoffs (8).

Despite the potential public health impacts of our study, the findings should be considered in light of a few limitations. Random nondifferential error associated with the use of dietary recalls and the calculation of EERs may have led to conservative estimates (50–53). In addition, because of the cross-sectional design of this study, the causal inference is limited, and findings need to be confirmed in future large-scale cohort studies. In the absence of longitudinal cohort studies in Canada, findings of this nationally representative survey can be useful for generating hypotheses. The third limitation is that self-reported measures were used to classify subjects with and without chronic diseases; however, the magnitude and direction of our results were consistent and robust. Another limitation is that we were unable to calculate the *trans* fat component score because of a lack of data in the CNF (20). Finally, because the CCHS 2.2 was conducted in 2004, it may not reflect current consumption trends although it is the only available national nutrition survey in Canada.

In conclusion, this study provides the first evidence, to our knowledge, that compliance to the 2015 DGA recommendations

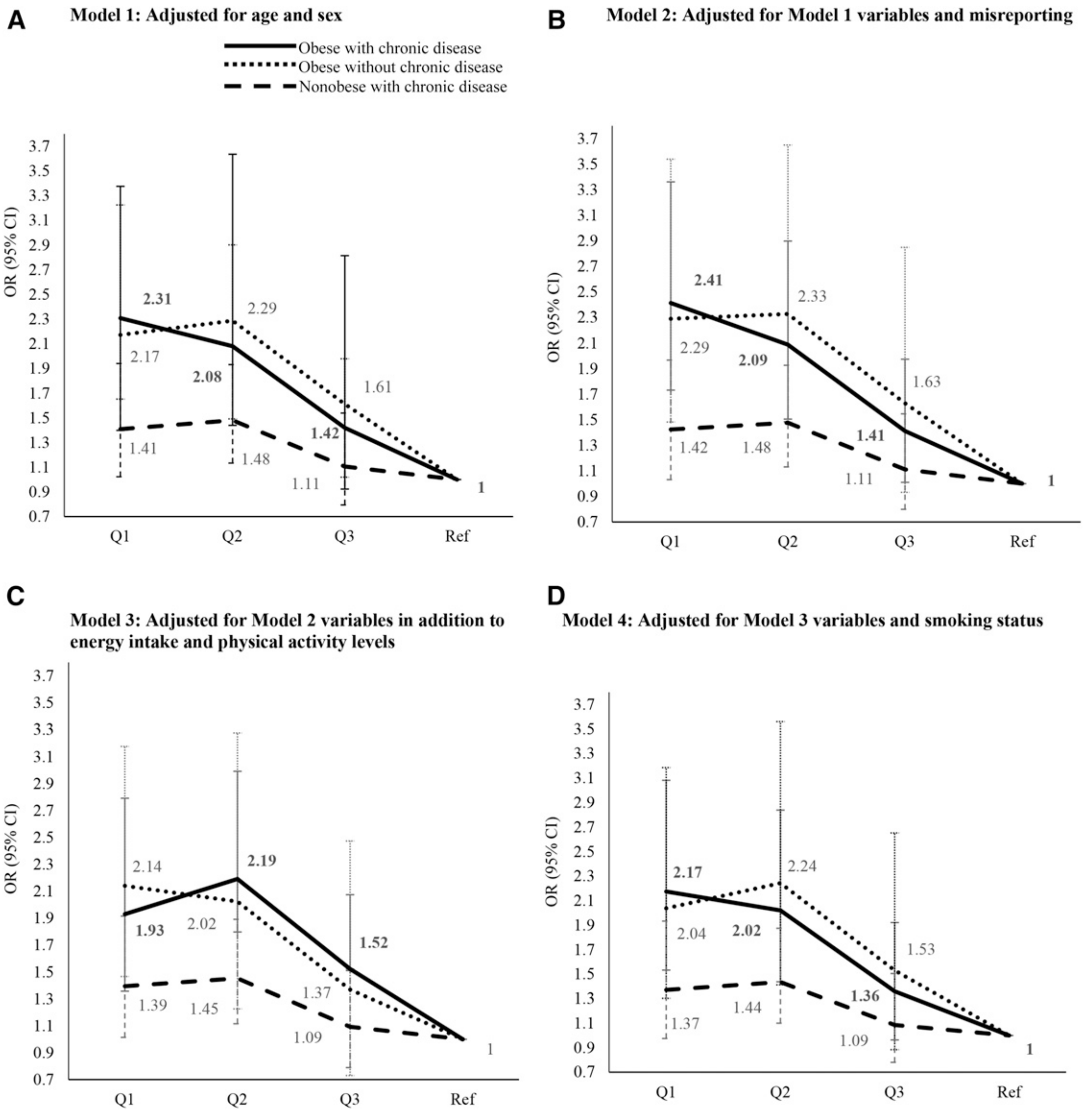

FIGURE 4 Weighted multivariate-adjusted ORs (95% CIs) for risk of obesity with and without ≥1 chronic disease across Q categories of the 2015 DGAI in Canadian adults (≥18 y old). (A) Adjusted for age and sex (model 1). (B) Adjusted as for model 1 and for misreporting (model 2). (C) Adjusted as for model 2 and for energy intake and physical activity levels (model 3). (D) Adjusted as for model 3 and for smoking status (model 4) (n = 11,748). Estimates were based on the multinomial logistic regression–generalized logit model. P-trend was based on the logistic regression coefficient for the 2015 DGAI as a continuous variable. For obese with chronic disease, P-trend < 0.0001; for obese without chronic disease, P-trend < 0.0003; and for nonobese with chronic disease, P-trend < 0.01. DGAI, Dietary Guidelines for Americans Adherence Index; Q, quartile.

is associated with higher diet quality and a lower risk of obesity with and without chronic diseases at the population level. Our findings also show the high validity and reliability of the 2015 DGAI as a measure of diet quality. Large-scale longitudinal studies are needed to prospectively examine the relation between following the 2015 DGA recommendations and weight gain in the presence and absence of metabolic disorders over long periods of time to be able to provide insights into the causal effects of following the 2015 USDA Food Patterns.

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The authors' responsibilities were as follows—MJ: conducted all statistical analyses, prepared the data tables, and drafted the manuscript; MJ and MRL: conceptualized and designed the study; and all authors: provided scientific input into the statistical analyses and manuscript and read and approved the final version of the manuscript. None of the authors reported a conflict of interest related to the study.

REFERENCES

1. Fardet A, Rock E. Toward a new philosophy of preventive nutrition: from a reductionist to a holistic paradigm to improve nutritional recommendations. Adv Nutr 2014;5:430–46.
2. US Department of Health and Human Services and US Department of Agriculture. 2015–2020 Dietary Guidelines for Americans [Internet]. 8th ed. December 2015 [cited 2016 May 30]. Washington (DC): US Department of Agriculture and Department of Health and Human Services. Available from: http://health.gov/dietaryguidelines/2015/guidelines/.
3. Liese AD, Krebs-Smith SM, Subar AF, George SM, Harmon BE, Neuhouser ML, Boushey CJ, Schap TE, Reedy J. The Dietary Patterns Methods Project: synthesis of findings across cohorts and relevance to dietary guidance. J Nutr 2015;145:393–402.

4. National Health and Medical Research Council. Eat for health: Australian Dietary Guidelines 2013 [Internet]. 2013 [cited 2016 May 30]. Available from: https://www.eatforhealth.gov.au/sites/default/files/files/the_guidelines/n55_australian_dietary_guidelines.pdf.
5. United States Department of Agriculture. Dietary Patterns. Nutrition Evidence Library [Internet]. 2014 [cited 2016 May 30]. Available from: http://www.nel.gov/topic.cfm?cat=3388.
6. Kennedy ET, Ohls J, Carlson S, Fleming K. The Healthy Eating Index: design and applications. J Am Diet Assoc 1995;95:1103–8.
7. Schulze MB, Hoffmann K. Methodological approaches to study dietary patterns in relation to risk of coronary heart disease and stroke. Br J Nutr 2006;95:860–9.
8. Fogli-Cawley JJ, Dwyer JT, Saltzman E, McCullough ML, Troy LM, Jacques PF. The 2005 Dietary Guidelines for Americans Adherence Index: development and application. J Nutr 2006;136: 2908–15.
9. Fogli-Cawley JJ, Dwyer JT, Saltzman E, McCullough ML, Troy LM, Meigs JB, Jacques PF. The 2005 Dietary Guidelines for Americans and risk of the metabolic syndrome. Am J Clin Nutr 2007;86:1193–201.
10. Imamura F, Jacques PF, Herrington DM, Dallal GE, Lichtenstein AH. Adherence to 2005 Dietary Guidelines for Americans is associated with a reduced progression of coronary artery atherosclerosis in women with established coronary artery disease. Am J Clin Nutr 2009;90:193–201.
11. Jessri M, Rashidkhani B, Hajizadeh B, Jessri M, Kreiger N, Bajdik CD. Adherence to dietary recommendations and risk of esophageal squamous cell carcinoma: a case-control study in Iran. Ann Nutr Metab 2011;59:166–75.
12. Mirmiran P, Hosseini-Esfahanil F, Jessri M, Mahan LK, Shiva N, Azizis F. Does dietary intake by Tehranian adults align with the 2005 dietary guidelines for Americans? Observations from the Tehran lipid and glucose study. J Health Popul Nutr 2011;29:39–52.
13. Hosseini-Esfahani F, Jessri M, Mirmiran P, Bastan S, Azizi F. Adherence to dietary recommendations and risk of metabolic syndrome: Tehran Lipid and Glucose Study. Metabolism 2010;59: 1833–42.
14. Jessri M, L'Abbe MR. The time for an updated Canadian Food Guide has arrived. Appl Physiol Nutr Metab 2015;;40:854–7.
15. Phillips CM, Dillon C, Harrington JM, McCarthy VJ, Kearney PM, Fitzgerald AP, Perry IJ. Defining metabolically healthy obesity: role of dietary and lifestyle factors. PLoS One 2013;8:e76188.
16. Health Canada. Canadian Community Health Survey Cycle 2.2 Nutrition (2004) [Internet]. 2006 [cited 2016 May 30]. Available from: http://www.hc-sc.gc.ca/fn-an/surveill/nutrition/commun/cchs_guide_escc-eng.php.
17. Béland Y, Dale V, Dufour J, Hamel M. The Canadian Community Health Survey: building on the success from the past. Proceedings of the American Statistical Association Joint Statistical Meeting, Section on Survey Research Methods. Minneapolis (MN): American Statistical Association; 2005.
18. United States Department of Agriculture Agricultural Research Service. USDA automated multiple-pass method [Internet]. 2009 [cited 2016 May 30]. Available from: http://www.ars.usda.gov/Services/docs.htm?docid=7710.
19. Moshfegh AJ, Borrud L, Perloff B, LaComb R. . Improved method for the 24-hour dietary recall for use in national surveys. FASEB J 1999: 13;A603 (abstr).
20. Health Canada. The Canadian Nutrient File. Ottawa (Canada): Nutrition Research Division Food Directorate; 2001.
21. Brisbois TD, Marsden SL, Anderson GH, Sievenpiper JL. Estimated intakes and sources of total and added sugars in the Canadian diet. Nutrients 2014;6:1899–912.
22. Johnson L, Mander AP, Jones LR, Emmett PM, Jebb SA. A prospective analysis of dietary energy density at age 5 and 7 years and fatness at 9 years among UK children. Int J Obes (Lond) 2008;32: 586–93.
23. Institute of Medicine. Dietary Reference Intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. Washington (DC): National Academy Press; 2005.
24. Jessri M, Lou YW, L'Abbe MR. Evaluation of different methods to handle misreporting in obesity research: evidence from the Canadian national nutrition survey. Br J Nutr 2016;115:147–59.
25. McCrory MA, McCrory MA, Hajduk CL, Roberts SB. Procedures for screening out inaccurate reports of dietary energy intake. Public Health Nutr 2002;5(6A):873–82.
26. Huang TT, Roberts SB, Howarth NC, McCrory MA. Effect of screening out implausible energy intake reports on relationships between diet and BMI. Obes Res 2005;13:1205–17.
27. ENVIRON International Corporation. What America drinks [Internet]. 2006 [cited 2016 May 30]. Available from: http://www.lanimoo.com/assets/pdf/What_America_Drinks_Report.pdf.
28. Garriguet D. Impact of identifying plausible respondents on the underreporting of energy intake in the Canadian Community Health Survey. Health Rep 2008;19:47–55.
29. Yeo D, Mantel H, Liu TP. Bootstrap variance estimation for the National Population Health Survey. Proceedings of the Annual Meeting of the American Statistical Association: survey research methods section. Baltimore (MD): American Statistical Association; 1999.
30. Fogli-Cawley JJ, Dwyer JT, Saltzman E, McCullough ML, Troy LM, Meigs JB, Jacques PF. The 2005 Dietary Guidelines for Americans and insulin resistance in the Framingham Offspring Cohort. Diabetes Care 2007;30:817–22.
31. Trochim WMK. Research methods knowledge base. Measurement validity types. The Web Center for Social Research Methods [Internet]. 2004 [cited 2016 May 30]. Available from: www.socialresearchmethods.net/.
32. Anderson AS, Bell A, Adamson A, Moynihan P. A questionnaire assessment of nutrition knowledge–validity and reliability issues. Public Health Nutr 2002;5:497–503.
33. Willett WC, Howe GR, Kushi LH. Adjustment for total energy intake in epidemiologic studies. Am J Clin Nutr 1997;65(4 Suppl):1220S–8S; discussion 1229S–31S.
34. Willett W, Stampfer MJ. Total energy intake: implications for epidemiologic analyses. Am J Epidemiol 1986;124:17–27.
35. Guenther PM, Kirkpatrick SI, Reedy J, Krebs-Smith SM, Buckman DW, Dodd KW, Casavale KO, Carroll RJ. The Healthy Eating Index-2010 is a valid and reliable measure of diet quality according to the 2010 Dietary Guidelines for Americans. J Nutr 2014;144:399–407.
36. Nunnally JC, Bernstein IH. Psychometric theory. 3rd ed. New York: McGraw-Hill; 1994.
37. Hanley JA. The robustness of the "binormal" assumptions used in fitting ROC curves. Med Decis Making 1988;8:197–203.
38. Janes H, Pepe MS. Adjusting for covariates in studies of diagnostic, screening, or prognostic markers: an old concept in a new setting. Am J Epidemiol 2008;168:89–97.
39. Wildman RP, Muntner P, Reynolds K, McGinn AP, Rajpathak S, Wylie-Rosett J, Sowers MR. The obese without cardiometabolic risk factor clustering and the normal weight with cardiometabolic risk factor clustering: prevalence and correlates of 2 phenotypes among the US population (NHANES 1999-2004). Arch Intern Med 2008;168: 1617–24.
40. Stefan N, Kantartzis K, Machann J, Schick F, Thamer C, Rittig K, Balletshofer B, Machicao F, Fritsche A, Haring HU. Identification and characterization of metabolically benign obesity in humans. Arch Intern Med 2008;168:1609–16.
41. Chiuve SE, Fung TT, Rimm EB, Hu FB, McCullough ML, Wang M, Stampfer MJ, Willett WC. Alternative dietary indices both strongly predict risk of chronic disease. J Nutr 2012;142:1009–18.
42. Jessri M, Nishi SK, L'Abbe MR. Assessing the nutritional quality of diets of Canadian adults using the 2014 Health Canada Surveillance Tool Tier System. Nutrients 2015;7:10447–68.
43. Jessri M, Nishi SK, L'Abbe MR. Assessing the nutritional quality of diets of Canadian children and adolescents using the 2014 Health Canada Surveillance Tool Tier System. BMC Public Health 2016; 16:381.
44. Guenther PM, Casavale KO, Reedy J, Kirkpatrick SI, Hiza HA, Kuczynski KJ, Kahle LL, Krebs-Smith SM. Update of the Healthy Eating Index: HEI-2010. J Acad Nutr Diet 2013;113:569–80.
45. Fung TT, Chiuve SE, McCullough ML, Rexrode KM, Logroscino G, Hu FB. Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women. Arch Intern Med 2008;168: 713–20.
46. Reedy J, Krebs-Smith SM, Miller PE, Liese AD, Kahle LL, Park Y, Subar AF. Higher diet quality is associated with decreased risk of all-cause, cardiovascular disease, and cancer mortality among older adults. J Nutr 2014;144:881–9.

47. Lavie CJ, De Schutter A, Milani RV. Healthy obese versus unhealthy lean: the obesity paradox. Nat Rev Endocrinol 2015;11:55–62.
48. Mendez MA, Popkin BM, Jakszyn P, Berenguer A, Tormo MJ, Sanchez MJ, Quiros JR, Pera G, Navarro C, Martinez C, et al. Adherence to a Mediterranean diet is associated with reduced 3-year incidence of obesity. J Nutr 2006;136:2934–8.
49. Lassale C, Fezeu L, Andreeva VA, Hercberg S, Kengne AP, Czernichow S, Kesse-Guyot E. Association between dietary scores and 13-year weight change and obesity risk in a French prospective cohort. Int J Obes (Lond) 2012;36:1455–62.
50. Freedman LS, Schatzkin A, Midthune D, Kipnis V. Dealing with dietary measurement error in nutritional cohort studies. J Natl Cancer Inst 2011;103:1086–92.
51. Harding AH, Sargeant LA, Welch A, Oakes S, Luben RN, Bingham S, Day NE, Khaw KT, Wareham NJ. Fat consumption and HbA(1c) levels: the EPIC-Norfolk study. Diabetes Care 2001;24:1911–6.
52. Armstrong BK, White E, Saracci R. Principles of exposure measurement in epidemiology. New York: Oxford University Press; 1992.
53. Trichopoulos D. Adipose tissue trans fatty acids and coronary heart disease. Lancet 1995;345:1108, author reply 1109–10.

Online Supplemental Material.

Supplemental Table 1. Scoring criteria of the 2015 Dietary Guidelines for Americans Adherence Index (DGAI) for individuals with 2000 kcal/day estimated energy requirement (EER)[1-4]

DGAI Components[5]					
	Scoring Criteria			Scoring Criteria	
	0 Point	1.0 point		0 Point	1.0 point
Food Intake Sub-score[6]			**Healthy Choice Sub-score[11]**		
Dark green vegetable *(cups/week)*	0	≥ 1.5	Whole grain *(% of grains)*	0	≥ 50%
Red/orange vegetables *(cup/week)*	0	≥ 5.5	Dietary fiber density (*gram/1000kcal)*	0	≥ 14
Legumes *(cup/week)*[7]	0	≥ 1.5	Total fat (*% Energy)*	≤ 10%, ≥ 45%	≥ 20%, ≤ 35%
Starchy vegetables *(cup/week)*[8]	0	5.0	Saturated fatty acid (*% Energy)*	≥ 15%	≤ 10%
Other vegetables *(cup/week)*	0	≥ 4.0	Cholesterol intake *(mg/day)*	≥ 450	≤ 300
Fruits *(cup/day)*	0	≥ 2	Low-fat dairy, and meat products *(%)*[12]	0%	≥ 75%
Variety of fruits and vegetables *(number of components)*[9]	0	6.0	Sodium *(mg/day)*	≥ 3450	≤ 2300
Grains *(oz-equivalent/day)*[8]	0	6.0	Alcohol *(drinks/day)*[13]	≥ 1.5	≤ 1.0
Meat and beans *(oz-equivalent/day)*[8]	0	26			
Dairy *(cup/day)*[8]	0	3			
Added sugar (*% Energy)*[10]	≥ 9%	≤ 6.0%			

Note: This table presents the updated 2015 version of the DGAI, which was previously published by Imamura et. al (2009) (with permission) (10).

[1]The 2015 Dietary Guidelines for Americans Adherence Index (DGAI) was developed based on the 2015 USDA Food Patterns (2), which has recommendations for 12 levels of energy requirement. The Canadian version of the 2015 DGAI has a total of 19 scores, since one of the Healthy Choice Sub-score components (*trans* fat) was not attainable.

[2]Estimated Energy Requirement was calculated by the IOM factorial equations using each participant's measured height, weight, physical activity level (PAL) (sedentary, low active, moderately active, highly active), age, and sex (23)

[3]One cup is defined as 237 ml (US), 0.946 cup in metric unit; 1 oz=28.35 grams

[4]Intermediate intakes between criteria for 0 and 1.0 points were scored proportionally.

[5]Possible scores for the 2015 DGAI ranged from 0-19, with higher scores indicating more healthful and varied dietary patterns.

[6]Possible maximum score of 11 points

[7]Legumes were assigned to the meat and beans group for individuals who needed to meet the 1-point criterion for meat and beans group and the extra servings were counted towards the vegetables group (legumes).

[8]An overconsumption penalty was imposed by reducing the score proportional to the amount of overconsumption up to 1.25 times higher than the recommended intake. Intakes ≥1.25 times the recommended amount were scored as 0.5 (truncation).

[9]Variety was determined by summing the 6 fruit and vegetables component scores.

[10]Added sugar available in the USDA Food Pattern for 2000-kcal/day energy requirement

[11]Possible maximum score of 8 points

[12]Adherence to recommendations of “low-fat dairy” and “low-fat meat” products was scored separately, each with a minimum score of 0 (for consuming 0% of dairy or meat products as low-fat) and maximum score of 0.5 (for consuming ≥75% of dairy or meat products as low-fat); intermediate percentages received proportional scores between 0 and 0.5. The final scores for adherence to low-fat dairy and meat were then summed for a maximum possible score of 1.0.

[13]One drink =118 ml wine;355 ml beer; or 45 ml distilled spirit

Online Supplemental Material.

Supplemental Table 2. Weighted mean 2015 Dietary Guidelines for Americans Adherence Index (DGAI) score among Canadian adults (≥18 years) according to the age group, sex and smoking status (n=11,748)[1-3]

	Mean ±SE	**P-value**
Gender		<0.0001
Males	8.56±0.06	
Females	9.28±0.05	
Age group		<0.0001
18 to 30 years	8.33±0.06	
30 to ≤50 years	8.65±0.07	
50 to ≤70 years	9.14±0.06	
>70 years	9.62±0.07	
Smokers		<0.0001
Daily	8.11±0.08	
Occasional	8.5±0.14	
Former	8.96±0.07	
Never	9.28±0.05	

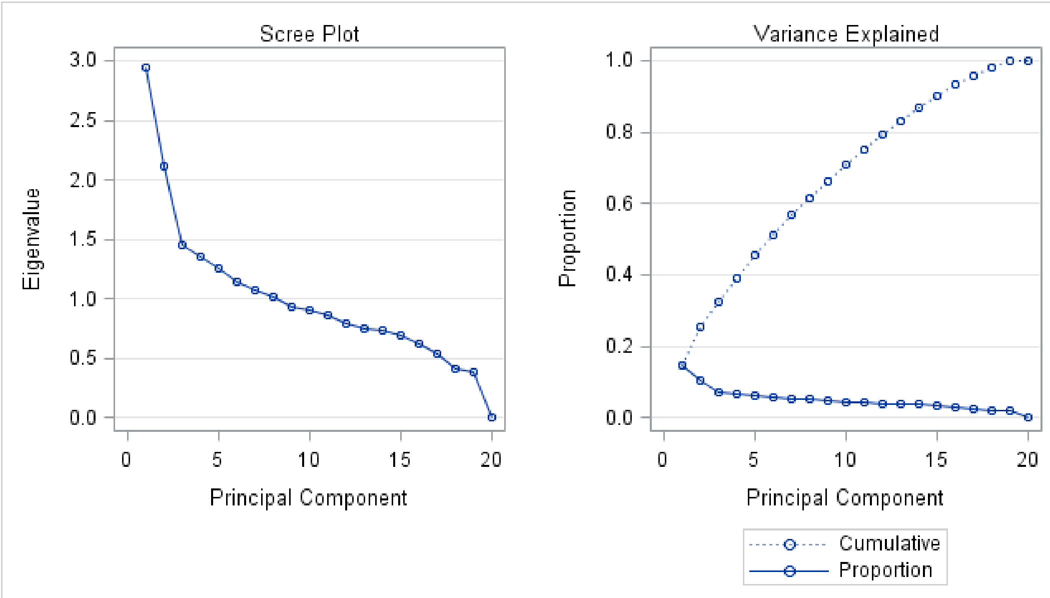
[1]Estimates are weighted means and bootstrapped variances (Balanced Repeated Replication technique) from the weighted analysis of covariance (ANCOVA).

[2]Values are adjusted for age and sex, unless otherwise noted. Age is adjusted for sex only and gender is adjusted for age only.

[3]Possible scores for the 2015 DGAI ranged from 0-19, with higher scores indicating more healthful and varied dietary patterns.

Online Supplemental Material.

Supplemental Figure 1. Eigenvalues of the correlation matrix and scree plot from weighted principle component analysis (PCA) of the 2015 Dietary Guidelines for Americans Adherence Index (DGAI) components showing the percentage of explained variance by each of the principal component dimensions among Canadian adults (≥18 years)(n=11,748)

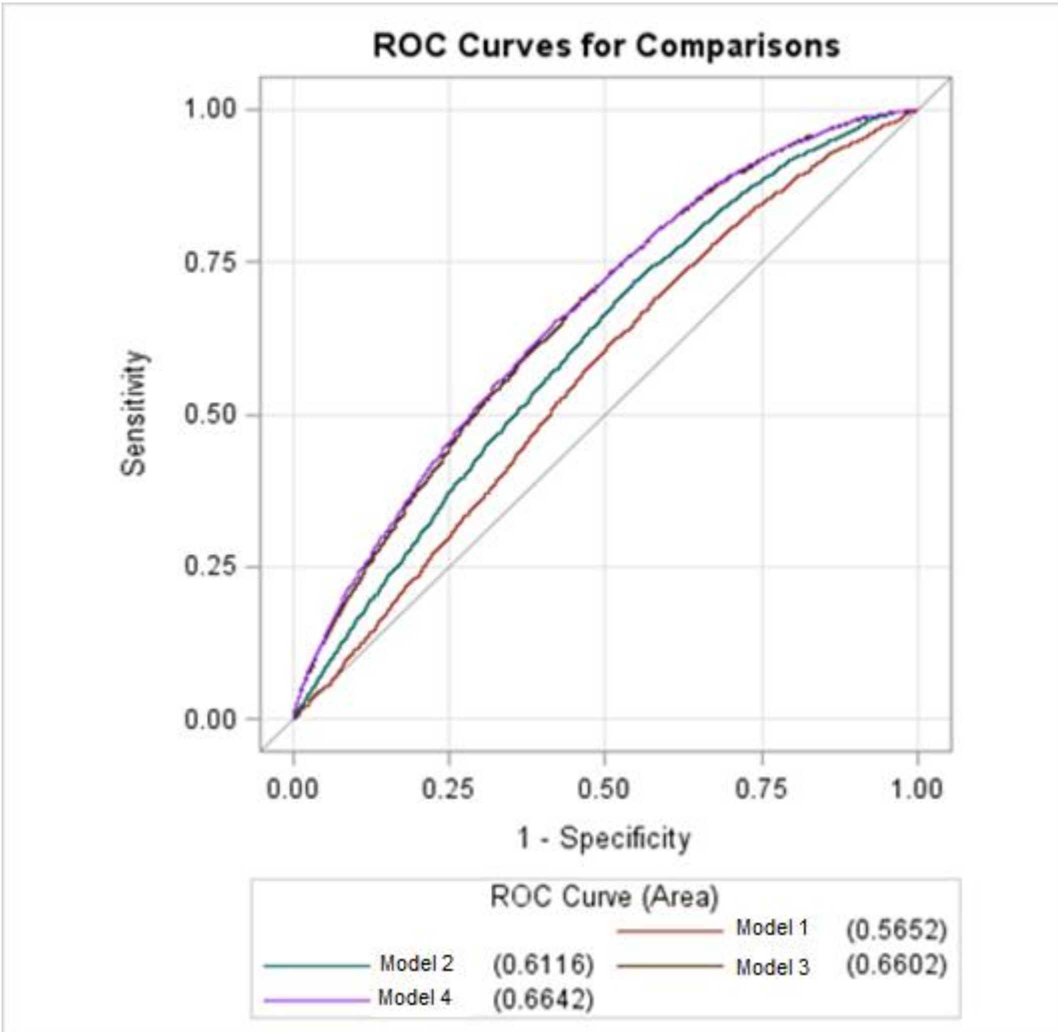


Eigenvalues of the Correlation Matrix

	Eigenvalue	Difference	Proportion	Cumulative
1	2.93654	0.82015	0.1468	0.1468
2	2.1164	0.66972	0.1058	0.2526
3	1.44668	0.09153	0.0723	0.325
4	1.35516	0.09417	0.0678	0.3927
5	1.26098	0.11697	0.063	0.4558
6	1.14401	0.07338	0.0572	0.513
7	1.07063	0.05484	0.0535	0.5665
8	1.01579	0.07748	0.0508	0.6173
9	0.93831	0.02844	0.0469	0.6642
10	0.90987	0.04115	0.0455	0.7097
11	0.86872	0.07849	0.0434	0.7532
12	0.79022	0.03352	0.0395	0.7927
13	0.75671	0.01849	0.0378	0.8305
14	0.73822	0.04706	0.0369	0.8674
15	0.69116	0.06985	0.0346	0.902
16	0.62131	0.08463	0.0311	0.933
17	0.53668	0.12348	0.0268	0.9599
18	0.4132	0.02381	0.0207	0.9805
19	0.38939	0.38939	0.0195	1

Online Supplemental Material.

Supplemental Figure 2. Weighted receiver operating characteristic (ROC) area under the curve (AUC) for the association of the 2015 Dietary Guidelines for Americans (DGAI) and obesity among Canadian adults (≥18 years)(n=11,748)



All ROC contrast estimation p-values for comparison of different models were statistically significant ($p<0.05$).

Model 1: Adjusted for age and sex; Model 2: Adjusted for Model 1 variables in addition to misreporting; Model 3: Adjusted for Model 2 variables in addition to energy intake and physical activity levels; Model 4: Adjusted for Model 3 variables in addition to smoking status