

Adherence to emerging plant-based dietary patterns and its association with cardiovascular disease risk in a nationally representative sample of Canadian adults

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ABSTRACT

Background: Little is known about the role of emerging plant-based dietary patterns in cardiovascular disease (CVD) risk at the national population level.

Objectives: The objectives of this research were to assess the validity and reliability of newly established plant-based dietary indices, and to evaluate their associations with CVD risk among Canadian adults.

Methods: Data were obtained from repeated 24-h dietary recalls of adult participants in the cross-sectional, nationally representative Canadian Community Health Survey cycle 2004 linked to health administrative databases ($n = 12,323$) and cycle 2015 ($n = 14,026$). Plant-based diet quality was assessed with a revised Plant-based Dietary Index (PDI), EAT–*Lancet* Reference Diet (ERD) score, and the latest Dietary Guidelines for Americans Adherence Index (DGAI) 2020. Weighted multivariate analyses were used for testing associations between diet quality and lifestyle characteristics, and weighted multivariable-adjusted Cox proportional hazards models for associations with CVD risk.

Results: Construct validity was confirmed for the revised PDI and DGAI 2020 (but not the ERD) because participants in the highest (healthiest) quartile, compared to those in the lowest (least healthy), were more likely to be female (mean \pm SE: 52.63% \pm 1.27% compared with 44.80% \pm 1.65% for revised PDI; 59.37% \pm 2.01% compared with 40.84% \pm 1.71% for DGAI 2020), older (mean \pm SE: 50.55 \pm 0.39 y compared with 45.56 \pm 0.43 y for revised PDI; 51.57 \pm 0.39 y compared with 46.35 \pm 0.54 y for DGAI 2020), to have postsecondary education (mean \pm SE: 32.36% \pm 1.55% compared with 21.12% \pm 1.31% for revised PDI; 34.17% \pm 2.69% compared with 17.87% \pm 0.98% for DGAI 2020), and less likely to be daily smokers (mean \pm SE: 8.21% \pm 1.0% compared with 17.06% \pm 1.45% for revised PDI; 7.36% \pm 1.71% compared with 21.53% \pm 1.58% for DGAI 2020) (P -trend $<$ 0.0001). No significant associations were observed between dietary index scores and CVD risk.

Conclusions: The revised PDI and DGAI 2020 provided valid and meaningful measures of plant-based eating among Canadians, whereas the validity of the ERD was not directly confirmed. Adherence to the plant-based dietary patterns was not associated with CVD risk. Future large-scale studies are necessary to further evaluate

the role of plant-based eating in CVD prevention. *Am J Clin Nutr* 2022;116:57–73.

Keywords: cardiovascular disease (CVD), dietary patterns, plant-based diet, guidelines, validity, reliability, dietary index, a priori methods, incidence, mortality

Introduction

Cardiovascular disease (CVD) is the leading driver of noncommunicable disease burden in the world, with trends revealing an almost double increase in CVD prevalent cases and a steady rise in the number of deaths over the past 30 y (1). Poor diet is the one of the most prevalent preventable behavioral risk factors for CVD, accounting for more than half of all CVD-related deaths globally (2).

In recent years, the focus of international dietary guidelines for CVD prevention has largely shifted to plant-based dietary patterns, which have been proven essential for the regulation of blood lipid concentrations, oxidative stress, inflammation,

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Supplemental Methods, Supplemental Figure 1, and Supplemental Tables 1–16 are available from the “Supplementary data” link in the online posting of the article and from the same link in the online table of contents at <https://academic.oup.com/ajcn/>.

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Abbreviations used: CCHS, Canadian Community Health Survey; CNF, Canadian Nutrient File; CVD, cardiovascular disease; DASH, Dietary Approaches to Stop Hypertension; DGA, Dietary Guidelines for Americans; DGAI, Dietary Guidelines for Americans Adherence Index; EER, estimated energy requirement; EI, energy intake; ERD, EAT–*Lancet* Reference Diet; NCI, National Cancer Institute; PDI, Plant-based Dietary Index; Q, quartile.

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visceral adiposity, and hyperglycemia (3–5). Adherence to a plant-based eating approach has also become a major public health priority in response to global food insecurity and environmental degradation. In an extensive report on healthy diets and sustainable food production, the 2019 EAT–Lancet Commission (6) concluded that a universal reference diet—high in plant protein, fruit, and vegetables and very low in animal products—was associated with the lowest risk of CVD incidence and mortality and with the least harmful environmental effects. Similarly, the need for a shift toward plant-based dietary patterns was echoed in the 2020–2025 Dietary Guidelines for Americans (DGA) (7), which strongly recommend “obtaining the majority of energy from plant-based foods, while limiting intakes of added sugars, solid fats, and sodium” for optimal cardiovascular health.

Although a growing number of studies have utilized various indices to measure adherence to plant-based eating patterns (8–10), only a few have explored associations with CVD risk in a general population (11–13) even though without an examination of performance of plant-based dietary indices. Using the Canadian national nutritional surveys linked with health administrative databases, the objectives of this research were: 1) to evaluate the validity and reliability of the emerging plant-based dietary indices, namely revised Plant-based Dietary Index (PDI) (14), the EAT–Lancet Reference Diet (ERD) score (15), and the Dietary Guidelines for Americans Adherence Index (DGAI) 2020 (16); and 2) to assess whether adherence to these dietary indices was associated with a lower risk of CVD incidence and mortality in a national sample of Canadian adults. We hypothesized that all dietary indices were valid and reliable measures of diet quality among Canadians, and that index scores would be significantly associated with CVD risk. To our knowledge, this is the first population-based study to update the 2015 DGAI (16) using the recently released 2020 DGA (7), and to compare the performance of emerging plant-based dietary indices in relation to CVD risk at the national population level.

Methods

Study population

Data used in this research were from the 2004 and 2015 cycles of the Canadian Community Health Survey (CCHS)-Nutrition (17, 18). The CCHS is a nationally representative cross-sectional survey, which collects information on health status, health determinants, and eating habits across Canada (19). Additional information on sampling design and survey procedures can be found elsewhere (17, 18). Data were collected in accordance with the Statistics Act of Canada with ethical approval granted by Statistics Canada. All participants gave informed consent to have their data shared and linked to health administrative databases.

The following exclusion criteria were applied to the CCHS-Nutrition 2015 cycle: individuals <18 y of age, breastfeeding women, individuals with invalid dietary recalls (as defined by Statistics Canada), and those with missing data on energy intake and physical activity. Exclusion criteria for CCHS-Nutrition 2004 included individuals <45 y and >80 y (for survival models), pregnant and breastfeeding women, individuals with invalid dietary recalls (as defined by Statistics Canada), residents of Quebec (for hospitalization records), those with heart diseases

at baseline, and individuals with missing data on energy intake (**Supplemental Methods**). Pregnant women were excluded from cycle 2004 but retained for cycle 2015 analyses because the 2015 Public Use Microdata File (PUMF) has pregnancy status masked to protect confidentiality (20). Missing measured height and weight data were handled by using self-reported anthropometric measurements and applying a correction factor determined by Statistics Canada (21). The final analytical samples for CCHS-Nutrition 2004 and 2015 were comprised of 12,323 and 14,026 Canadian adults, respectively (**Supplemental Figure 1**).

All descriptive analyses on validity and reliability of the dietary indices, as well as population adherence, were conducted on CCHS-Nutrition 2015, whereas the longitudinal associations between dietary indices and CVD outcomes were attained using CCHS-Nutrition 2004 linked to health administrative databases (**Supplemental Methods**).

Exposure and outcome measurement

Dietary assessment.

In both CCHS-Nutrition cycles, data on sociodemographic and lifestyle characteristics were captured through administration of a general health questionnaire. Detailed dietary intake data were collected using two 24-h dietary recalls (17, 18) via the Automated Multiple-Pass Method (AMPM) (22). Nutrient and energy compositions of reported foods were retrieved from Health Canada’s Canadian Nutrient File (CNF) (23, 24).

Outcome ascertainment.

The primary outcomes of interest were CVD incidence and mortality, which were represented by a single variable—CVD events—defined as CVD incident hospitalization cases or deaths. CVD events were defined by a group of disorders of the heart and blood vessels coded according to the International Statistical Classification of Diseases and Related Health Problems, 10th revision [ICD-10 (25)] as described previously (26, 27).

Dietary index scores used

Dietary Approaches to Stop Hypertension (DASH) index (28) (0–90 points) was chosen as a robust, widely used index with substantial known benefits for cardiovascular health to serve primarily as a reference tool for assessing the performance of the emerging plant-based dietary indices in this research (**Supplemental Table 1**). Unlike other DASH indices, the index developed by Matsunaga et al. (28) depends on calorie-based standards in equivalent units with 0–10 scores assigned to every component, in accordance with the energy levels recommended in the DASH eating plan (7, 29). The PDI by Satija et al. (14) (0–90 points) provides a scoring system that distinguishes between plant-based and animal-based products, consisting of 18 food groups which are further ranked into quintiles based on distributions of respondents’ intake (**Supplemental Table 2**). To address the differences in distribution of intake due to using 24-h dietary recalls in this research, as opposed to FFQs used in the original research by Satija et al. (14), scoring criteria of the original index were modified as follows: continuous proportional scores were assigned for consumptions >0 but below the 5th quintile, and a maximum score of 5 was assigned to individual

intakes above the 5th quintile. The ERD score (0–14 points) was developed by Knuppel et al. (15) and reflects recommended consumption amounts in the ERD (6) (Supplemental Table 3). Finally, the DGAI 2020 (0–19 points) was devised by updating the 2015 DGAI (16) to assess adherence to the food-based energy recommendations and nutrient requirements laid out in the DGA 2020 and USDA Food Patterns (7) (Supplemental Table 4). We evaluated adherence to the DGA 2020 (7) instead of Canada's Food Guide 2019 (30) because the former uniquely provides quantitative dietary pattern recommendations for 12 energy levels based on age, sex, and daily physical activity. In the present study, the DGAI 2020 included 19 components owing to insufficient data on *trans* fat (one of the DGA nutrient components) in the CNF (2324). A penalty of ≤ 0.5 points for overconsumption amounts ≥ 1.25 times higher than the recommended intake was exercised for energy-dense food groups, including dairy, proteins, starchy vegetables, and grains (31).

Statistical analyses

Statistical analyses were carried out using SAS software (version 9.4; SAS Institute Inc.). The complex sampling framework of the CCHS was addressed by using bootstrap balanced repeated replication method for variance estimation (32). To ensure national representativeness of findings, the sample survey weights provided by Statistics Canada were applied to all statistical analyses. All a priori diet quality indices were normally distributed and divided into quartiles on the basis of population distributions. Weighted and covariate-adjusted associations between dietary scores and lifestyle and sociodemographic characteristics were explored using multivariable linear regression and least-squares means for continuous and categorical variables, respectively. Statistical significance was defined by a 2-tailed P value < 0.05 . Descriptive analyses focused on the first 24-h dietary recall from CCHS-Nutrition 2015.

Handling measurement errors in dietary intake reporting.

In line with previous studies, systematic measurement error (misreporting) was accounted for by comparing estimated energy requirements (EERs) with energy intakes (EIs) (33). To calculate EERs, the Institute of Medicine (IOM) factorial equations were applied, based on age, sex, BMI, height, weight, and physical activity level. Under-reporters were represented by an $EI < 70\%$ of EER, plausible reporters by $70\% \leq EI \leq 142\%$ of EER, and over-reporters by an $EI > 142\%$ of EER (34, 35). Random measurement error was addressed using the National Cancer Institute (NCI) method (36) for estimating usual dietary intake (Supplemental Methods).

Testing the validity and reliability of diet quality indices.

Face validity and construct validity were assessed to test whether the 4 dietary indices could distinguish between population subgroups with known differences in dietary habits (37, 38), and to evaluate trends in the association of dietary scores with energy and nutrient intakes. Because higher quality diets have been previously reported among women, older individuals, and nonsmokers, we also explored concurrent-criterion validity

through examining dietary index scores in these 3 groups. Weighted Pearson correlation coefficients were calculated to ensure that dietary indices could measure diet quality of Canadians irrespective of diet quantity (i.e., EI). Finally, internal consistency of indices was evaluated using Cronbach's coefficient α by determining the degree of association between the different components of an index (39).

Because of the role of obesity (defined by a $BMI \geq 30$ kg/m²) as a known mediator in the relationship between diet and CVD, the association of diet quality indices with risk of obesity was also examined as an additional test for construct validity, using weighted multinomial logistic regression in 4 successive a priori-defined models. Because some obese individuals are shown to be "metabolically healthy" (40, 41), we further stratified regression models to study the associations between dietary index scores and obesity with and without chronic disease (i.e., self-reported heart disease, cancer, diabetes, and hypertension).

Examining the association of diet quality index scores with CVD outcomes.

The NCI method (36) was applied to both 24-h dietary recalls available from CCHS-Nutrition 2004 to address random measurement error and generate respondents' "usual" index score distributions (Supplemental Methods). Weighted Cox proportional hazards models with person-days as the main time-metric were fitted to evaluate associations between adherence to the 4 dietary indices and CVD risk. All Cox models tested for sex interaction. Because scores were treated as continuous in the models, HRs and 95% CIs were computed at the mid-point of each index quintiles, with the 10th percentile serving as a reference.

Results

Validity and reliability of diet quality indices

All index scores were normally distributed (data not shown). Estimated mean (\pm SE) DASH index, revised PDI, ERD, and DGAI 2020 scores were 41.19 ± 0.25 out of 90, 38.8 ± 0.17 out of 90, 8.94 ± 0.04 out of 14, and 8.80 ± 0.04 out of 19, respectively. These results indicate that Canadians adhered to $< 50\%$ of the recommendations outlined in the DASH diet, plant-based dietary patterns, and DGA 2020, and to 64% of recommendations proposed in the ERD.

The face validity and construct validity of the DASH index, revised PDI, and DGAI 2020 were confirmed because the total scores were associated with a number of sociodemographic and lifestyle characteristics (Table 1, Supplemental Table 5). Respondents in the fourth quartile (highest diet quality) of these 3 index scores, compared with those in the first quartile (lowest diet quality), were more likely to be older and in the possession of higher education, and much less likely to be daily smokers and breakfast skippers (P -trend < 0.0001). As for the ERD score, significant positive associations with higher diet quality scores were found only for immigration status (P -trend = 0.0113). After adjusting for age, and sex, higher diet quality was significantly associated with higher percentage of energy from carbohydrates and densities of fiber, vitamin C, folate, folacin, magnesium, and iron across all indices (P -trend < 0.0001) (Table 2,

TABLE 1 Weighted sociodemographic and lifestyle characteristics by quartiles of the DASH index, revised PDI, ERD score, and DGAI 2020 among Canadian adults (≥ 18 y old) from CCHS-Nutrition 2015¹

	DASH index				Revised PDI				ERD score				DGA1 2020			
	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4		
Median score ²	26.75	54.94	29.20	48.25	6.32	10.0	6.38	11.23								
Female, %	40.29 \pm 1.50	61.40 \pm 1.26**	44.80 \pm 1.65	52.63 \pm 1.27*	51.90 \pm 3.42	51.87 \pm 1.23	40.84 \pm 1.71	59.37 \pm 2.01**								
Age, y	45.83 \pm 0.78	51.64 \pm 0.43**	45.56 \pm 0.43	50.55 \pm 0.39**	50.17 \pm 1.02	47.51 \pm 0.50	46.35 \pm 0.54	51.57 \pm 0.39**								
BMI, kg/m ²	27.96 \pm 0.21	26.68 \pm 0.20**	28.39 \pm 0.23	26.52 \pm 0.18**	27.57 \pm 0.30	27.07 \pm 0.25	27.94 \pm 0.24	26.74 \pm 0.22*								
Obesity, %	29.77 \pm 1.96	23.74 \pm 2.03*	26.69 \pm 1.20	22.26 \pm 1.63*	24.94 \pm 1.67	23.21 \pm 0.95	26.02 \pm 1.14	21.45 \pm 0.98*								
Obese with ≥ 1 chronic disease, %	19.40 \pm 1.61	14.25 \pm 1.34*	22.49 \pm 2.99	14.44 \pm 1.46	15.97 \pm 1.98	16.44 \pm 1.53	17.80 \pm 1.49	14.50 \pm 1.28								
Having ≥ 1 chronic disease, %	55.56 \pm 3.21	53.35 \pm 2.02	61.34 \pm 3.16	50.65 \pm 2.44*	55.05 \pm 3.76	54.27 \pm 2.75	56.74 \pm 2.0	51.46 \pm 4.37								
Met physical activity guidelines, ³ %	38.94 \pm 2.48	47.81 \pm 4.51*	40.30 \pm 2.46	45.38 \pm 3.47	42.74 \pm 2.27	44.77 \pm 3.35	38.54 \pm 1.78	48.15 \pm 3.72**								
Current daily smokers, %	19.44 \pm 1.63	6.48 \pm 0.80**	17.06 \pm 1.45	8.21 \pm 1.0**	13.71 \pm 1.38	12.75 \pm 1.90	21.53 \pm 1.58	7.36 \pm 1.71**								
Alcohol consumption, ⁴ yes	34.32 \pm 1.54	32.13 \pm 3.72	37.17 \pm 3.57	34.77 \pm 3.52	37.74 \pm 1.99	36.23 \pm 4.12	40.45 \pm 1.66	29.37 \pm 3.85*								
Household education, %																
Less than secondary school graduation	10.01 \pm 0.97	4.76 \pm 0.38**	9.01 \pm 0.69	5.18 \pm 0.45**	7.93 \pm 1.71	6.81 \pm 0.41	10.36 \pm 1.14	4.50 \pm 0.34**								
Postsecondary education	27.25 \pm 2.03	45.47 \pm 1.74**	29.85 \pm 1.55	43.55 \pm 1.88**	33.50 \pm 4.97	37.26 \pm 1.44	26.28 \pm 2.26	46.64 \pm 1.59**								
Respondent education, %																
Less than secondary school graduation	17.05 \pm 0.99	8.76 \pm 0.78**	15.33 \pm 0.78	9.20 \pm 0.53**	14.13 \pm 1.98	11.48 \pm 1.11	17.88 \pm 1.01	8.36 \pm 0.72**								
Postsecondary education	18.88 \pm 0.95	33.26 \pm 2.70**	21.12 \pm 1.31	32.36 \pm 1.55**	23.21 \pm 2.34	27.73 \pm 2.92	17.87 \pm 0.98	34.17 \pm 2.69**								
Marital status, %																
Married	50.68 \pm 5.62	57.90 \pm 6.18*	49.35 \pm 5.01	61.39 \pm 5.31**	56.74 \pm 5.44	51.64 \pm 9.28	45.25 \pm 6.67	60.60 \pm 6.92**								
Single	22.57 \pm 4.69	17.89 \pm 4.37*	23.42 \pm 4.37	15.78 \pm 3.55**	18.60 \pm 3.97	21.92 \pm 7.08	26.38 \pm 6.04	16.14 \pm 4.49**								
Immigrant, %	24.71 \pm 3.63	33.55 \pm 6.15*	21.39 \pm 5.12	34.34 \pm 4.23**	21.57 \pm 6.16	28.88 \pm 6.32*	20.82 \pm 2.76	36.17 \pm 6.94**								
Excellent self-perceived health status, %	15.55 \pm 1.04	23.85 \pm 1.09**	17.74 \pm 1.17	22.78 \pm 1.01*	19.03 \pm 1.11	19.99 \pm 0.87	15.46 \pm 0.97	23.88 \pm 1.93*								
Highest income, %	12.46 \pm 0.86	15.69 \pm 1.30*	15.09 \pm 1.12	15.32 \pm 1.05	15.72 \pm 1.78	13.85 \pm 1.26	11.39 \pm 1.45	16.49 \pm 1.26**								
Breakfast skippers, %	15.17 \pm 1.67	4.79 \pm 0.97**	14.84 \pm 2.19	4.98 \pm 1.01**	9.95 \pm 3.35	10.15 \pm 1.71	17.45 \pm 2.27	1.65 \pm 1.23**								

¹ $n = 14,026$. A smaller sample size due to exclusion of "valid skip" and "not stated" responses in CCHS-Nutrition 2015 was used in the analyses of BMI (in kg/m²) ($n = 9407$); household education (%) ($n = 13,996$); respondent education (%) ($n = 13,970$); marital status (%) ($n = 14,015$); self-perceived health status (%) ($n = 14,007$); and income (%) ($n = 14,019$). All values are weighted means or percentages with bootstrapped variances (determined with the use of the balanced repeated replication technique) \pm SEs unless otherwise indicated. Covariate-adjusted associations between the scores and continuous and categorical variables were determined using 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. Only results for quartiles 1 and 4 are shown; see Supplemental Table 5 for results across all quartiles. CCHS, Canadian Community Health Survey; DASH, Dietary Approaches to Stop Hypertension; DGAI, Dietary Guidelines for Americans Adherence Index; ERD, EAT-Lancet Reference Diet; PDI, Plant-based Diet Index.

²Higher scores indicated higher diet quality.

³According to current physical activity guidelines, Canadian adults should perform 150 min moderate/vigorous-intensity physical activity per week.

⁴Assessed as "alcohol intake from food sources (g)" and therefore representing any amount of alcohol consumed from the first 24-h dietary recall.

***Significant P -trend: # P -trend < 0.05; ** P -trend < 0.0001.

TABLE 2 Weighted mean daily intakes of macro- and micronutrients as percentage of energy or per 1000 kcal (nutrient density) by quartile category of dietary scores among Canadian adults (≥ 18 y old) from the CCHS-Nutrition¹

	Model	DASH index				Revised PDI				ERD score				DGAI 2020			
		Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4		
Energy intake, kcal/d	a	1903.24 ± 26.36	1742.80 ± 26.31**	1801.31 ± 36.99	2008.51 ± 29.10**	1967.20 ± 35.90	1790.45 ± 30.12**	1983.92 ± 44.67	1806.05 ± 19.31*								
	b	2282.71 ± 31.40	2231.45 ± 18.36	2276.92 ± 20.15	2292.11 ± 16.76	2315.41 ± 22.26	2229.68 ± 18.44**	2306.78 ± 21.89	2256.37 ± 17.65*								
Carbohydrate, % of energy	a	45.23 ± 0.33	51.48 ± 0.77**	41.97 ± 1.10	51.93 ± 0.71**	45.32 ± 0.66	49.17 ± 0.99**	44.08 ± 0.65	50.71 ± 0.57**								
	b	44.58 ± 0.35	50.60 ± 0.77**	40.83 ± 1.05	51.39 ± 0.79**	44.68 ± 0.67	48.33 ± 0.93**	43.65 ± 0.56	50.07 ± 0.59**								
Fiber density, g/1000 kcal	a	6.51 ± 0.13	13.61 ± 0.35**	7.21 ± 0.14	12.42 ± 0.31**	8.36 ± 0.37	10.68 ± 0.30**	6.31 ± 0.15	13.57 ± 0.20**								
	b	6.24 ± 0.14	13.24 ± 0.38**	6.61 ± 0.16	12.14 ± 0.35**	8.04 ± 0.37	10.26 ± 0.29**	6.21 ± 0.15	13.40 ± 0.20**								
Added sugar, ² % of energy	a	12.69 ± 0.32	6.74 ± 0.25**	36.34 ± 2.43	47.69 ± 1.29**	10.25 ± 0.47	8.32 ± 0.23**	11.81 ± 0.45	6.51 ± 0.17**								
	b	12.66 ± 0.34	6.73 ± 0.30**	48.17 ± 3.26	54.67 ± 1.48	10.28 ± 0.49	8.36 ± 0.24**	11.68 ± 0.46	6.35 ± 0.20**								
Total fat, % of energy	a	33.78 ± 0.32	29.90 ± 0.45**	34.27 ± 0.37	30.59 ± 0.52**	34.07 ± 0.56	30.79 ± 0.49**	35.46 ± 0.41	29.25 ± 0.35**								
	b	34.48 ± 0.39	30.87 ± 0.54**	35.34 ± 0.38	31.09 ± 0.67**	34.71 ± 0.65	31.66 ± 0.52**	35.90 ± 0.38	29.91 ± 0.46**								
Saturated fat, % of energy	a	11.30 ± 0.20	9.09 ± 0.15**	11.95 ± 0.12	9.15 ± 0.17**	11.30 ± 0.32	9.84 ± 0.18**	12.63 ± 0.18	8.60 ± 0.10**								
	b	11.54 ± 0.22	9.43 ± 0.18**	12.38 ± 0.14	9.33 ± 0.22**	11.53 ± 0.34	10.16 ± 0.19**	12.74 ± 0.16	8.78 ± 0.13**								
MUFAs, % of energy	a	12.65 ± 0.11	11.16 ± 0.25*	12.26 ± 0.14	11.85 ± 0.25	12.72 ± 0.23	11.39 ± 0.25**	12.84 ± 0.15	11.13 ± 0.25**								
	b	12.98 ± 0.13	11.60 ± 0.30*	12.71 ± 0.14	12.09 ± 0.32	13.03 ± 0.27	11.79 ± 0.27**	13.09 ± 0.15	11.49 ± 0.33**								
PUFAs, % of energy	a	6.85 ± 0.08	6.89 ± 0.14	7.01 ± 0.21	6.81 ± 0.15	7.0 ± 0.12	6.73 ± 0.13*	6.85 ± 0.15	6.77 ± 0.09								
	b	6.92 ± 0.10	7.0 ± 0.16	7.13 ± 0.20	6.84 ± 0.18*	7.05 ± 0.12	6.81 ± 0.14*	6.90 ± 0.15	6.85 ± 0.10								
Linoleic acid, % of energy	a	5.73 ± 0.07	5.84 ± 0.15	5.89 ± 0.18	5.81 ± 0.14	5.85 ± 0.10	5.74 ± 0.12	5.81 ± 0.12	5.66 ± 0.08								
	b	5.81 ± 0.09	5.96 ± 0.17	6.01 ± 0.18	5.84 ± 0.17*	5.92 ± 0.11	5.83 ± 0.12	5.87 ± 0.12	5.75 ± 0.09								
Linolenic acid, % of energy	a	0.75 ± 0.01	0.79 ± 0.02	0.76 ± 0.02	0.76 ± 0.02	0.78 ± 0.04	0.75 ± 0.02	0.74 ± 0.01	0.78 ± 0.02*								
	b	0.75 ± 0.01	0.79 ± 0.02	0.76 ± 0.02	0.76 ± 0.02	0.78 ± 0.03	0.75 ± 0.02	0.74 ± 0.01	0.78 ± 0.02*								
Protein, % of energy	a	18.47 ± 0.35	15.88 ± 0.15**	19.22 ± 0.21	15.13 ± 0.15**	18.16 ± 0.22	16.08 ± 0.25**	15.94 ± 0.21	18.26 ± 0.17**								
	b	18.16 ± 0.28	15.43 ± 0.16**	18.88 ± 0.21	15.01 ± 0.14**	17.91 ± 0.21	15.71 ± 0.20**	15.79 ± 0.23	18.02 ± 0.21**								
Alcohol, % of energy	a	2.52 ± 0.18	2.73 ± 0.40	4.54 ± 0.88	2.34 ± 0.30*	2.45 ± 0.27	3.96 ± 0.71*	4.52 ± 0.36	1.78 ± 0.22**								
	b	2.78 ± 0.24	3.10 ± 0.28	4.95 ± 0.73	2.51 ± 0.19**	2.70 ± 0.22	4.30 ± 0.56*	4.66 ± 0.28	2.0 ± 0.17**								
Cholesterol density, mg/1000 kcal	a	190.68 ± 5.69	111.71 ± 4.27**	200.89 ± 4.35	100.97 ± 3.60**	199.46 ± 4.80	112.61 ± 2.86**	174.79 ± 4.94	127.15 ± 3.98**								
	b	189.04 ± 7.52	108.66 ± 5.99**	200.99 ± 6.17	102.0 ± 5.51**	198.52 ± 4.89	110.64 ± 4.13**	173.11 ± 5.99	124.53 ± 5.28**								
Calcium density, mg/1000 kcal	a	348.18 ± 6.26	500.96 ± 9.23**	472.87 ± 9.65	402.69 ± 5.38**	424.11 ± 11.31	439.91 ± 9.08*	405.89 ± 7.36	457.12 ± 9.08**								
	b	343.0 ± 6.03	493.05 ± 8.29**	463.59 ± 9.16	399.03 ± 5.82**	418.02 ± 10.51	431.26 ± 8.74*	401.74 ± 7.56	450.66 ± 8.27**								

(Continued)

TABLE 2 (Continued)

Model	DASH index				Revised PDI				ERD score				DGAI 2020			
	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4
Vitamin A density in retinol activity equivalent, µg/1000 kcal	289.47 ± 10.47	465.08 ± 27.10**	361.72 ± 10.76	365.96 ± 13.87	382.89 ± 10.87	357.82 ± 12.72	288.47 ± 10.68	495.06 ± 19.57**	372.50 ± 13.24	342.48 ± 15.82*	285.21 ± 13.25	488.86 ± 24.40**	372.50 ± 13.24	342.48 ± 15.82*	285.21 ± 13.25	488.86 ± 24.40**
Vitamin D density, µg/1000 kcal	2.53 ± 0.18	2.75 ± 0.10	3.83 ± 0.18	2.04 ± 0.07**	3.44 ± 0.19	2.13 ± 0.10**	2.45 ± 0.18	2.87 ± 0.08*	3.44 ± 0.19	2.13 ± 0.10**	2.45 ± 0.18	2.87 ± 0.08*	3.44 ± 0.19	2.13 ± 0.10**	2.45 ± 0.18	2.87 ± 0.08*
Vitamin C density, mg/1000 kcal	2.49 ± 0.16	2.68 ± 0.09	3.34 ± 0.16	2.03 ± 0.07**	3.40 ± 0.17	2.06 ± 0.12**	2.44 ± 0.15	2.83 ± 0.10*	3.40 ± 0.17	2.06 ± 0.12**	2.44 ± 0.15	2.83 ± 0.10*	3.40 ± 0.17	2.06 ± 0.12**	2.44 ± 0.15	2.83 ± 0.10*
Sodium density, g/1000 kcal	38.30 ± 2.67	78.82 ± 1.96**	38.10 ± 3.25	72.39 ± 1.70**	49.88 ± 3.51	60.0 ± 2.18*	30.2 ± 1.71	81.82 ± 3.10**	48.09 ± 3.29	57.25 ± 2.64	29.94 ± 1.40	81.1 ± 3.56**	1481.02 ± 25.79	1497.13 ± 23.80	1579.95 ± 29.55	1389.67 ± 20.24**
Thiamin density, mg/1000 kcal	1763.34 ± 27.86	1249.24 ± 13.55**	1622.86 ± 20.99	1360.11 ± 14.97**	1481.02 ± 25.79	1469.20 ± 24.91	1556.14 ± 29.92	1355.0 ± 17.50**	1461.86 ± 25.17	1469.20 ± 24.91	1556.14 ± 29.92	1355.0 ± 17.50**	1461.86 ± 25.17	1469.20 ± 24.91	1556.14 ± 29.92	1355.0 ± 17.50**
Riboflavin density, mg/1000 kcal	0.84 ± 0.01	0.89 ± 0.02*	0.88 ± 0.01	0.88 ± 0.03	0.81 ± 0.01	0.90 ± 0.04*	0.79 ± 0.02	0.93 ± 0.01**	0.81 ± 0.01	0.88 ± 0.04	0.78 ± 0.02	0.92 ± 0.01**	0.81 ± 0.01	0.88 ± 0.04	0.78 ± 0.02	0.92 ± 0.01**
Niacin density in niacin equivalents, mg/1000 kcal	1.02 ± 0.02	1.06 ± 0.01*	1.12 ± 0.02	0.97 ± 0.01**	1.09 ± 0.02	1.0 ± 0.01*	1.01 ± 0.03	1.07 ± 0.02	1.09 ± 0.02	1.0 ± 0.01*	1.01 ± 0.03	1.07 ± 0.02	1.09 ± 0.02	1.0 ± 0.01*	1.01 ± 0.03	1.07 ± 0.02
Vitamin B-6 density, mg/1000 kcal	22.58 ± 0.35	19.35 ± 0.26**	22.53 ± 0.28	19.39 ± 0.26**	21.86 ± 0.50	20.64 ± 0.45*	19.40 ± 0.25	22.67 ± 0.29**	21.57 ± 0.49	20.19 ± 0.41**	19.40 ± 0.25	22.67 ± 0.29**	21.57 ± 0.49	20.19 ± 0.41**	19.40 ± 0.25	22.67 ± 0.29**
Vitamin B-12 density, µg/1000 kcal	0.84 ± 0.02	1.0 ± 0.04**	0.86 ± 0.02	0.94 ± 0.04**	0.96 ± 0.04	0.88 ± 0.03*	0.72 ± 0.02	1.14 ± 0.03**	0.96 ± 0.04	0.88 ± 0.03*	0.72 ± 0.02	1.14 ± 0.03**	0.96 ± 0.04	0.88 ± 0.03*	0.72 ± 0.02	1.14 ± 0.03**
Naturally occurring folate density, µg/1000 kcal	2.62 ± 0.09	1.94 ± 0.09**	2.86 ± 0.09	1.75 ± 0.10**	2.71 ± 0.10	1.89 ± 0.08**	2.31 ± 0.07	2.20 ± 0.12	2.71 ± 0.10	1.89 ± 0.08**	2.31 ± 0.07	2.20 ± 0.12	2.71 ± 0.10	1.89 ± 0.08**	2.31 ± 0.07	2.20 ± 0.12
Folacin density from food sources, µg/1000 kcal	87.86 ± 3.15	153.17 ± 3.51**	95.88 ± 1.92	138.78 ± 3.70**	110.78 ± 5.66	125.35 ± 2.93*	86.45 ± 2.06	157.82 ± 2.05**	107.33 ± 5.64	120.44 ± 2.63*	85.21 ± 1.64	155.64 ± 2.16**	107.33 ± 5.64	120.44 ± 2.63*	85.21 ± 1.64	155.64 ± 2.16**
	161.27 ± 3.44	202.90 ± 3.61**	165.40 ± 2.32	198.17 ± 3.01**	157.84 ± 5.16	192.32 ± 4.32**	157.88 ± 2.74	203.90 ± 2.36**	157.84 ± 5.16	192.32 ± 4.32**	157.88 ± 2.74	203.90 ± 2.36**	157.84 ± 5.16	192.32 ± 4.32**	157.88 ± 2.74	203.90 ± 2.36**
	157.81 ± 3.53	197.64 ± 4.27**	158.72 ± 2.66	195.82 ± 3.39**	154.63 ± 5.49	187.62 ± 4.37**	155.94 ± 2.62	200.75 ± 2.34**	154.63 ± 5.49	187.62 ± 4.37**	155.94 ± 2.62	200.75 ± 2.34**	154.63 ± 5.49	187.62 ± 4.37**	155.94 ± 2.62	200.75 ± 2.34**

(Continued)

TABLE 2 (Continued)

	Model	DASH index				Revised PDI				ERD score				DGAI 2020			
		Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4	Quartile 1	Quartile 4								
Phosphorus density, mg/1000 kcal	a	659.45 ± 6.56	745.53 ± 6.04**	740.86 ± 11.55	671.67 ± 6.39**	722.11 ± 8.42	683.52 ± 6.08*	635.56 ± 6.67	766.62 ± 7.77**								
	b	647.19 ± 6.50	728.30 ± 6.12**	732.18 ± 12.01	663.38 ± 7.63**	709.81 ± 8.77	666.79 ± 6.66*	628.25 ± 8.0	755.49 ± 8.32**								
Magnesium density, mg/1000 kcal	a	139.08 ± 3.41	214.15 ± 2.12**	153.98 ± 1.80	192.97 ± 2.11**	162.17 ± 3.99	178.26 ± 1.94**	135.09 ± 2.19	210.88 ± 1.76**								
	b	134.66 ± 3.53	207.68 ± 2.28**	145.34 ± 1.97	189.50 ± 2.19**	157.47 ± 3.91	171.67 ± 1.93*	132.82 ± 1.83	207.18 ± 1.95**								
Iron density, mg/1000 kcal	a	6.59 ± 0.89	7.06 ± 0.07**	6.56 ± 0.06	7.09 ± 0.07**	6.46 ± 0.10	6.99 ± 0.13*	6.03 ± 0.09	7.45 ± 0.14**								
	b	6.47 ± 0.09	6.89 ± 0.08*	6.36 ± 0.07	7.0 ± 0.07**	6.35 ± 0.10	6.83 ± 0.13*	5.97 ± 0.08	7.35 ± 0.13**								
Zinc density, mg/1000 kcal	a	5.84 ± 0.13	5.67 ± 0.10	5.96 ± 0.09	5.48 ± 0.08**	5.96 ± 0.15	5.47 ± 0.06**	5.10 ± 0.15	6.22 ± 0.18**								
	b	5.73 ± 0.12	5.53 ± 0.13	5.83 ± 0.08	5.41 ± 0.10*	5.86 ± 0.16	5.34 ± 0.07**	5.04 ± 0.13	6.14 ± 0.21**								
Potassium density, mg/1000 kcal	a	1282.15 ± 16.91	1804.70 ± 17.14**	1369.28 ± 14.75	1637.84 ± 13.13**	1555.38 ± 26.41	1515.58 ± 13.60	1198.37 ± 17.01	1831.62 ± 20.80**								
	b	1247.95 ± 23.52	1751.16 ± 24.17**	1301.36 ± 23.62	1616.15 ± 15.97**	1519.36 ± 21.15	1462.19 ± 22.20	1183.80 ± 16.40	1805.73 ± 32.68**								
Caffeine density, mg/1000 kcal	a	116.04 ± 6.20	96.03 ± 3.47*	93.52 ± 4.40	94.80 ± 2.88	91.67 ± 3.98	102.62 ± 5.39	112.22 ± 13.65	86.37 ± 4.47*								
	b	107.63 ± 6.05	82.81 ± 3.35**	80.87 ± 4.30	91.38 ± 2.63	84.85 ± 3.47	92.11 ± 5.26	104.90 ± 12.39	75.24 ± 3.57*								
Moisture density, ⁵ g/1000 kcal	a	1387.53 ± 26.73	1731.01 ± 39.97**	1534.38 ± 41.56	1487.13 ± 21.78	1382.12 ± 28.91	1605.48 ± 29.66**	1455.71 ± 37.84	1658.0 ± 31.66**								
	b	1285.84 ± 25.52	1567.88 ± 37.05**	1366.86 ± 34.37	1443.19 ± 20.48	1294.74 ± 29.27	1469.33 ± 26.32**	1378.56 ± 30.76	1536.44 ± 24.86**								
Glycemic index density, ⁶ per 1000 kcal	a	35.55 ± 0.66	32.98 ± 0.67*	37.48 ± 1.21	28.65 ± 0.66**	31.34 ± 0.75	35.71 ± 1.0**	38.37 ± 1.41	29.88 ± 0.72**								
	b	32.55 ± 0.67	27.98 ± 0.54**	32.71 ± 1.23	27.73 ± 0.58**	28.95 ± 0.72	31.79 ± 0.81*	35.85 ± 1.43	25.92 ± 1.03**								
Energy density, ⁷ per 1000 kcal	a	1.29 ± 0.03	0.97 ± 0.01**	1.40 ± 0.09	0.89 ± 0.01**	1.09 ± 0.03	1.18 ± 0.05	1.52 ± 0.10	0.83 ± 0.01**								
	b	1.20 ± 0.03	0.83 ± 0.01**	1.27 ± 0.07	0.87 ± 0.01**	1.02 ± 0.02	1.07 ± 0.05	1.43 ± 0.09	0.70 ± 0.03**								

¹n = 14,026. All values are weighted means with bootstrapped variances (determined using the balanced repeated replication technique) ± SEs unless otherwise indicated. Covariate-adjusted associations between the scores and continuous variables were determined with the use of weighted multivariable linear regression. Values were adjusted for age and sex (model a), with the addition of misreporting status (model b). Only results for quartiles 1 and 4 are shown; see Supplemental Table 6 for results across all quartiles. CCHS, Canadian Community Health Survey; DASH, Dietary Approaches to Stop Hypertension; DGAI, Dietary Guidelines for Americans Adherence Index; ERD, EAT–Lancet Reference Diet; PDI, Plant-based Diet Index.

²Because added sugars are not included in the Canadian Nutrient File, the method proposed by Brisbois et al. (59) was used to derive estimates of added sugars.

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

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

⁵Based on water content in food sources.

⁶Estimated by assigning the mean values reported in the International Glycemic Index Table (60, 61) to each of the Bureau of Nutritional Sciences food categories (62), as described previously (63, 64).

⁷The dietary energy density was calculated by dividing the total energy from foods (kcal) by the total weight of foods (g) (with the exclusion of beverages) (65, 66).

***Significant P-trend: * P-trend < 0.05; ** P-trend < 0.0001.

Supplemental Table 6). Adjusting for misreporting status did not have a profound effect on the direction and significance of any of these trends. When individual index components were examined, respondents in the highest quartile categories of the DASH index, revised PDI, ERD, and DGAI 2020 had the highest individual component scores (**Supplemental Tables 7–10**).

To explore population adherence to dietary recommendations, multidimensional radar plots were used representing percentages of compliers, intermediate compliers, and noncompliers (**Figure 1**). Overall, none of the 4 dietary patterns were fully adhered to by Canadians. In fact, the ERD score was the only index with a good degree of compliance: >80% of respondents complied well with recommendations in 7 out of 14 component categories. Poor compliance was commonly observed for plant-based food categories, whereas the animal-based components “fish” and “eggs” appeared to be the main source of compliance. Concurrent-criterion validity was confirmed for the DASH index, revised PDI, and DGAI 2020 (**Supplemental Table 11**). After adjusting for age and sex, mean total scores were significantly higher in women than in men ($P < 0.05$), older respondents than in younger individuals ($P < 0.0001$), and in nonsmokers than in daily and occasional smokers ($P < 0.0001$). The ERD score did not display any significant linear trends among the different categories.

Lastly, internal consistency tests revealed standardized Cronbach’s α coefficients of 0.73, 0.45, 0.35, and 0.23 for the DGAI 2020, DASH index, revised PDI, and ERD score, respectively. The DASH index, revised PDI, and ERD total scores had significant and positive correlations with their respective individual components ($P < 0.05$) (**Supplemental Tables 12–15**). To ensure diet quality was measured independently of diet quantity, the correlations between EI and the total scores of each index were explored. Results showed slightly negative correlations for the DASH index ($r = -0.17$) and DGAI 2020 ($r = -0.15$), and slightly positive correlations for the revised PDI ($r = 0.07$) and ERD score ($r = 0.01$). All correlation coefficients between EI and total and component scores were small.

Adherence to the diet quality indices and risk of obesity

The multivariable-adjusted odds of being obese were significantly higher in the lowest (unhealthiest) quartiles than for those in the highest quartiles (healthiest, reference) of the DASH index (OR: 1.45; 95% CI: 1.13, 1.85), revised PDI (OR: 1.63; 95% CI: 1.30, 2.05), and DGAI 2020 scores (OR: 1.52; 95% CI: 1.24, 1.86) (all P -trends < 0.05) (model 4 in **Figure 2A, B, D**). Although the probability of being obese also increased in the lowest compared with the highest quartile of the ERD score across all models (**Figure 2C**), none of the trends reached statistical significance. Jointly stratifying respondents by weight and chronic disease status showed less clear trends (**Figure 3**). The ORs of being unhealthy and obese were significantly increased in quartile 1 compared with quartile 3 of the DASH index (Q1 OR: 1.54; 95% CI: 1.02, 2.34; Q3 OR: 1.13; 95% CI: 0.78, 1.62) and DGAI 2020 (Q1 OR: 1.53; 95% CI: 1.05, 2.23; Q3 OR: 1.36; 95% CI: 0.87, 2.14) (P -trends < 0.05). The probability of being obese without a chronic disease (healthy and obese), on the other hand, was significantly higher in the lowest as compared to the highest

quartiles of the revised PDI (OR: 1.67; 95% CI: 0.92, 3.03) and DGAI 2020 (OR: 1.75; 95% CI: 1.18, 2.61) (P -trends < 0.05). High adherence to the EAT–*Lancet* planetary diet was not associated with a lower risk of obesity (with or without chronic disease) or decreased odds of a chronic disease without obesity (**Figure 3C**).

Adherence to the diet quality indices and risk of CVD

CCHS-Nutrition 2004 was used for evaluating the association of diet quality indices with CVD outcomes. Compliance to dietary patterns was relatively similar between the two Canadian national nutrition surveys (CCHS 2004 and CCHS 2015) (**Supplemental Table 16**). During a total of 80,529 person-years of follow-up, 748 incident CVD events were documented. After accounting for multiple potential confounders in the multivariable-adjusted models, there were no significant associations between usual dietary scores and CVD events (**Table 3**). Effect modification by sex was significant across all dietary scores in both the age- and multivariable-adjusted models (P -interaction < 0.0001 for all).

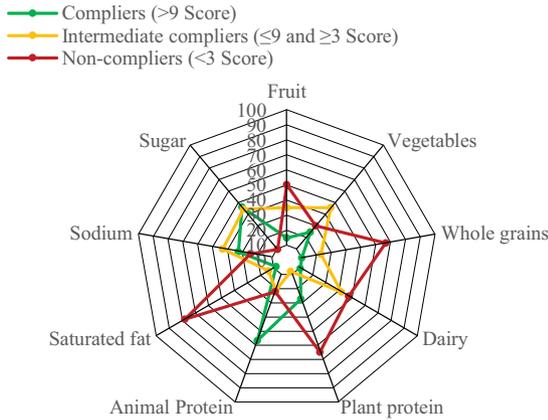
Discussion

In a nationally representative sample of Canadian adults, our findings revealed consistent and strong evidence to support the validity of the DASH index, revised PDI, and DGAI 2020 for measuring diet quality, whereas the validity of the ERD score was not directly confirmed. In the multivariable-adjusted model, we found no significant associations between adherence to the dietary indices and CVD incidence and mortality.

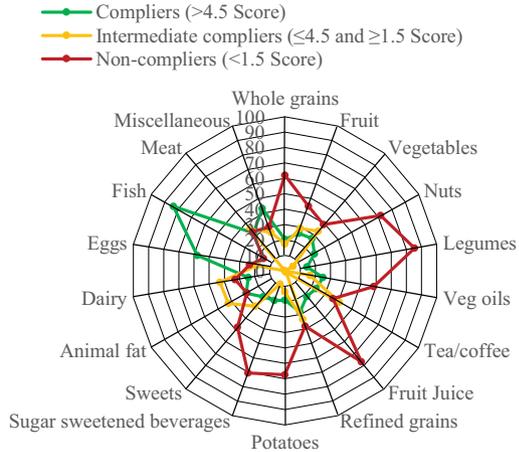
To our knowledge, this is the first study to evaluate the validity and reliability of emerging plant-based dietary indices at the national population level. We confirmed the construct validity of the revised PDI and DGAI 2020 to be as robust as that of the DASH index, established through associations with sociodemographic and lifestyle characteristics. Furthermore, closer adherence to the revised PDI and DGAI 2020 was associated with higher nutrient quality (irrespective of quantity), higher index subcomponent scores, and a lower risk of obesity after adjusting for a number of confounders. These findings are supported by previous studies using PDIs and the DGAI, whereby higher index scores were significantly associated with lower risk of obesity (16, 42). Conversely, the ERD score displayed weak and inconsistent evidence to support its validity and reliability, which may be explained in light of its crude scoring system.

Our study did not find any significant associations between plant-based dietary patterns and CVD incidence and mortality. This is in line with a previous nationally representative study conducted in the United States (11), which revealed non-significant associations between PDIs and CVD mortality after stratifying analyses by sex. Nonetheless, mixed results were reported by the same group in a consecutive community-based analysis where CVD incidence and mortality were explored separately (13). More recently, Keaver et al. (12) extended the use of PDIs to further distinguish the quality of animal- and plant-based foods in another nationally representative study in the United States and found no significant associations with heart disease mortality. Whereas our findings are directly in line with

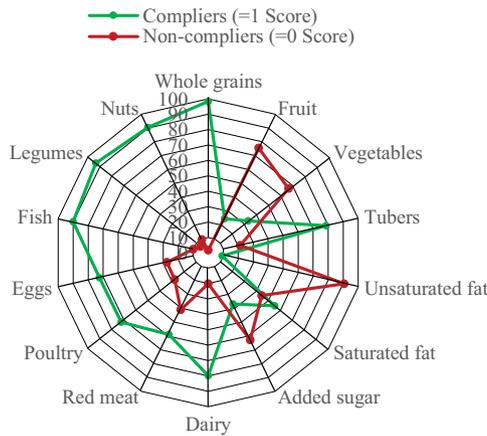
A DASH Components



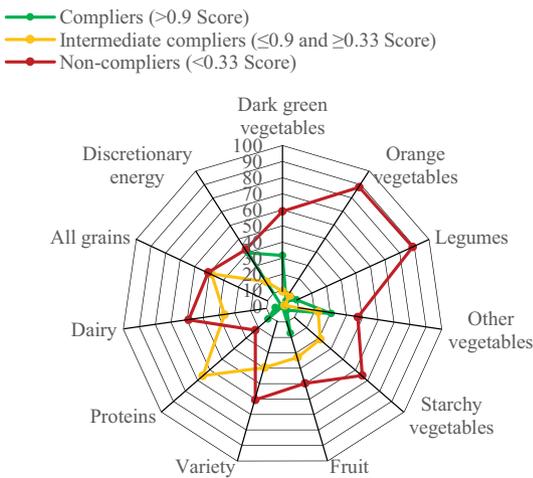
B revised PDI Components



C ERD Components



D DGAI “Food intake” Subscore Components



E DGAI “Healthy Choice” Subscore Components

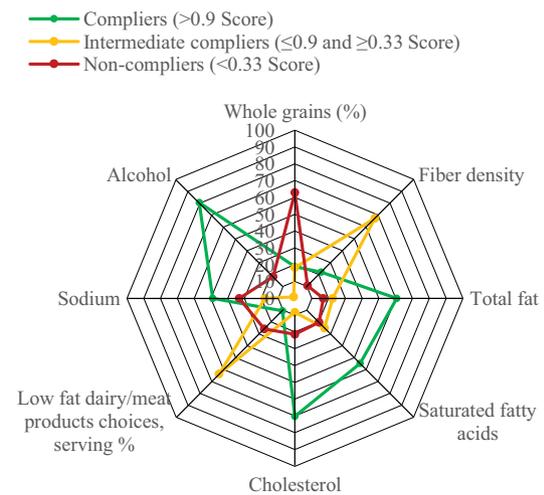


FIGURE 1 Weighted percentages with bootstrapped variances (determined using the balanced repeated replication technique) of compliance for each of the components of the DASH index (A), revised PDI (B), ERD score (C), DGAI 2020 food intake subscore (D), and DGAI 2020 healthy choice subscore (E) among Canadian adults (≥ 18 y old) from the Canadian Community Health Survey 2015 ($n = 14,026$). Each spoke of the radar plot depicts an individual component and each line color represents a different category of compliance. Prevalence is expressed as 0%–100%. All differences between compliance groups across the dietary indices’ components were assessed with a chi-square test and were statistically significant ($P < 0.0001$). DASH, Dietary Approaches to Stop Hypertension; DGAI, Dietary Guidelines for Americans Adherence Index; ERD, EAT–Lancet Reference Diet; PDI, Plant-based Diet Index.

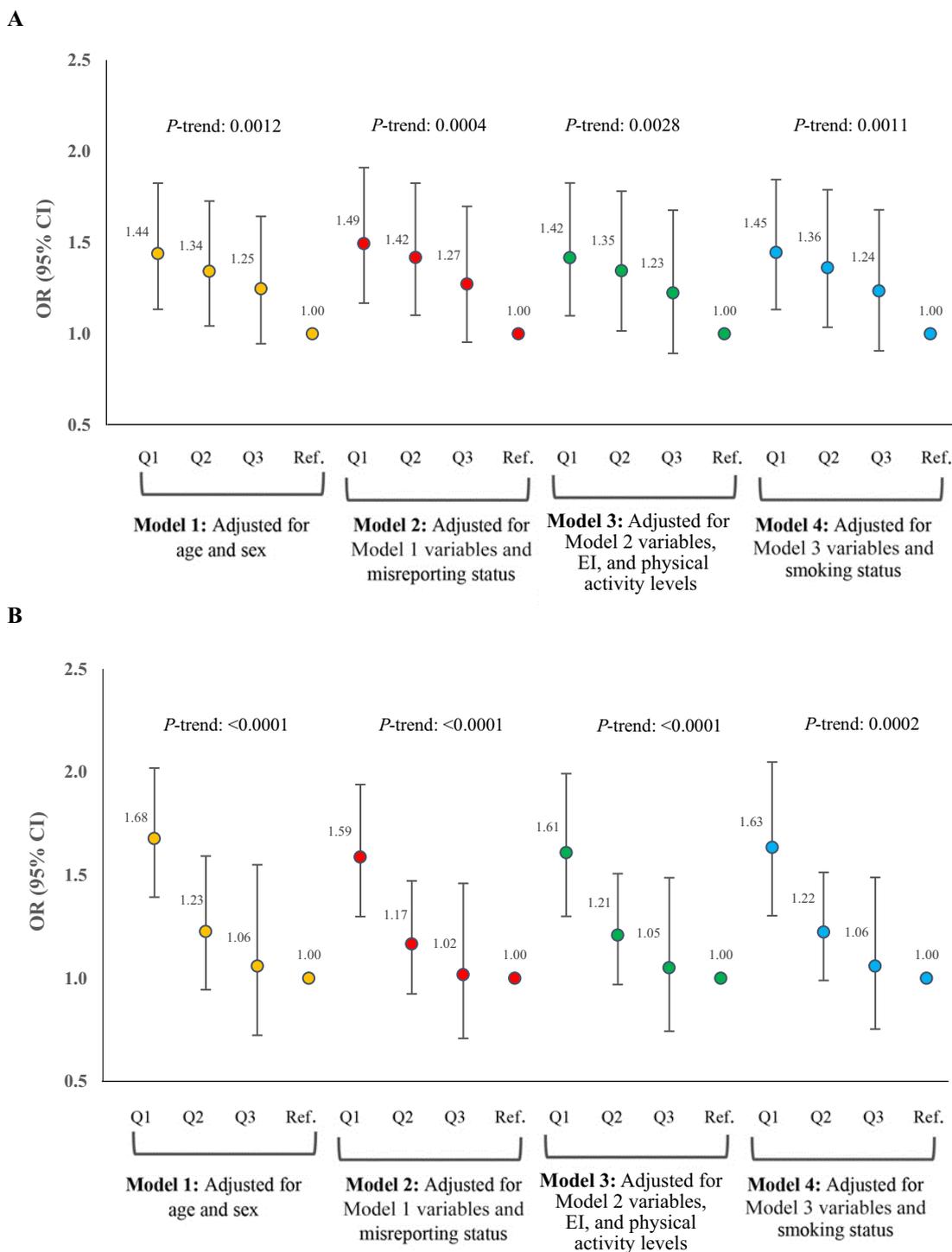
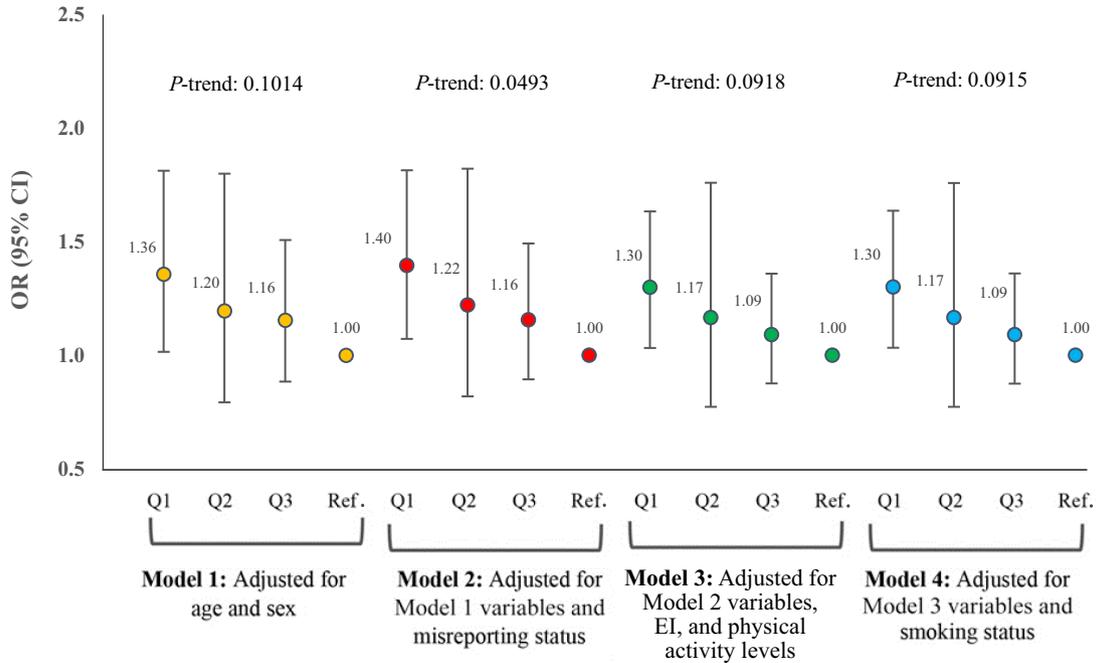


FIGURE 2 Continued.

previous nationally representative studies in the United States, they are in contrast with the majority of previous prospective cohort studies to have utilized PDIs (14, 43, 44) or overall diet quality indices such as the DASH index (44–47), although most of these involved smaller samples or specific populations. Such conflicting results could be attributed to inconsistencies

in the definitions of CVD and plant-based dietary patterns, lack of uniform methodological and statistical approaches in the utilization of a priori dietary pattern scores, as well as the inclusion of highly variable confounders. Another plausible explanation is that a minimum level of adherence to plant-based eating is to be achieved before health benefits are observed (11,

C



D

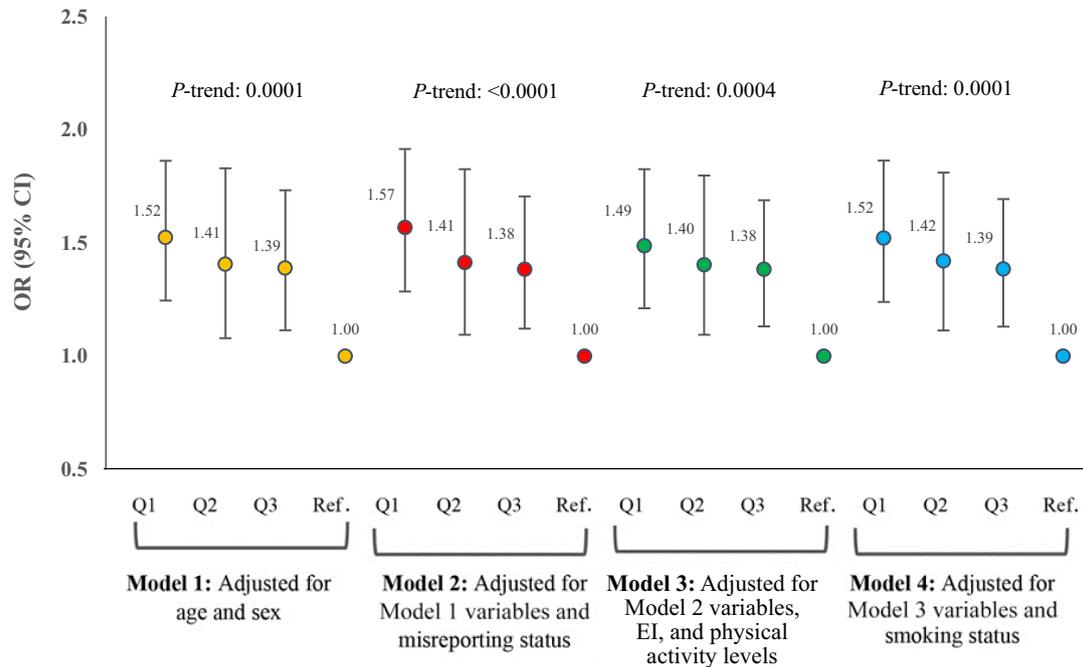


FIGURE 2 Weighted multivariate-adjusted ORs (95% CIs) with bootstrapped variances (determined using the balanced repeated replication technique) for obesity risk [BMI (in kg/m²) ≥30] across quartile categories of the Dietary Approaches to Stop Hypertension index (A), revised Plant-based Diet Index (B), EAT–Lancet Reference Diet score (C), and Dietary Guidelines for Americans Adherence Index 2020 (D) in Canadian adults (≥18 y old) from the Canadian Community Health Survey–Nutrition 2015 (n = 14,026). Estimates were based on the multinomial logistic regression generalized logit model. P-trend was based on the logistic regression coefficient for the index scores as continuous variables. EI, energy intake; Q, quartile.

48, 49) and because general populations tend to adhere less to plant-based dietary patterns, health benefits might be difficult to capture. As well, compared to nationally representative analyses, cohort studies are prone to selection bias, which could lead to

higher scores (healthier dietary patterns). Importantly, the non-significant associations found in this study do not undermine the well-established role of plant-based eating patterns in reducing CVD events and mortality at the population level (14, 15, 50, 51).

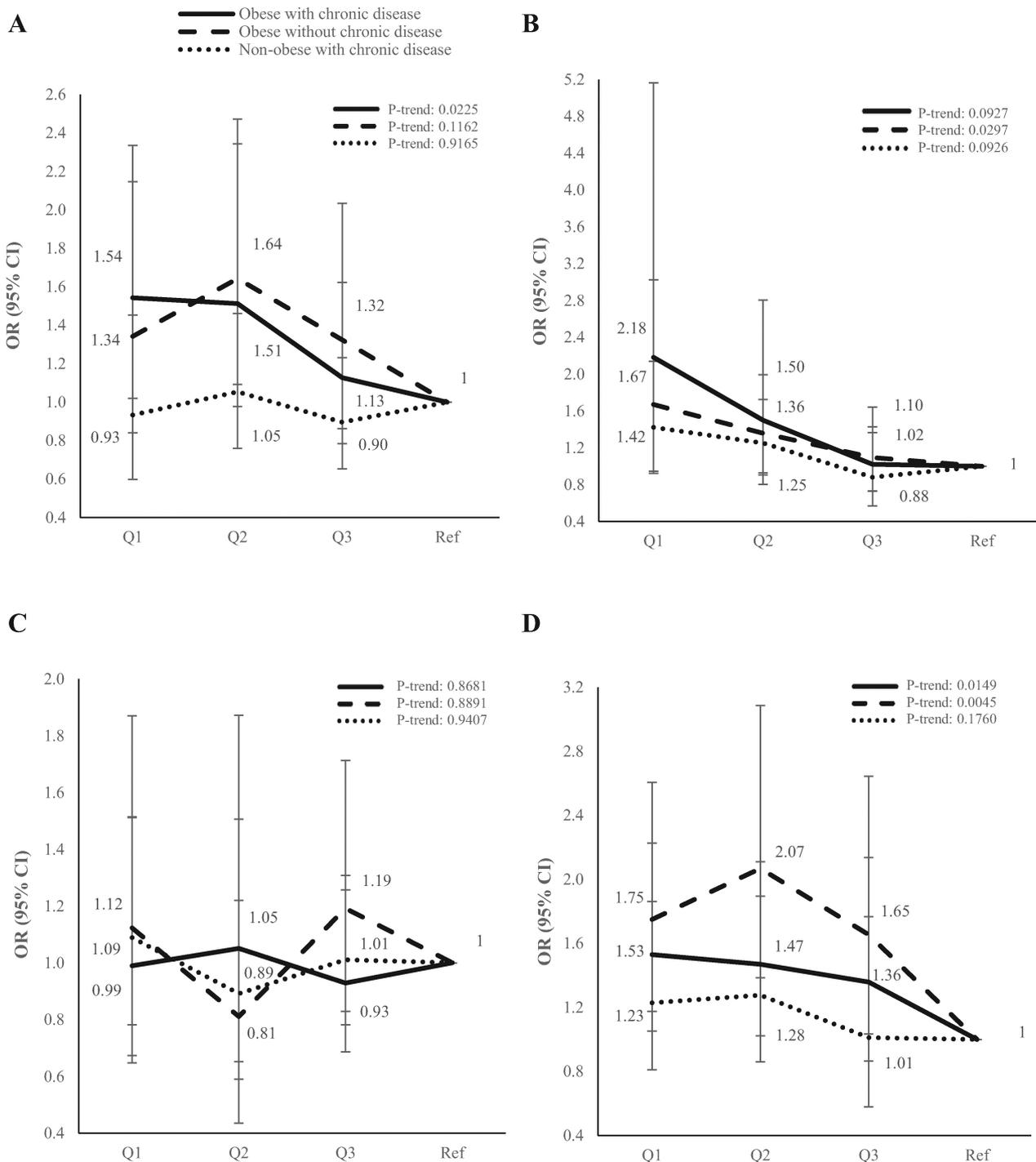


FIGURE 3 Weighted multivariate-adjusted ORs (95% CIs) with bootstrapped variances (determined using the balanced repeated replication technique) for risk of obesity with and without ≥ 1 chronic disease across quartile categories of the Dietary Approaches to Stop Hypertension index (A), revised Plant-based Diet Index (B), EAT–Lancet Reference Diet score (C), and Dietary Guidelines for Americans Adherence Index 2020 (D) in Canadian adults (≥ 18 y old) from the Canadian Community Health Survey–Nutrition 2015 ($n = 14,026$). All models were adjusted for age, sex, misreporting, energy intake, physical activity levels, and smoking status. Estimates were based on the multinomial logistic regression generalized logit model. *P*-trends are shown in the following order: 1) obese with chronic disease; 2) obese without chronic disease; 3) nonobese with chronic disease. Q, quartile.

Another important aspect of this study was inclusion of the ERD score as an emerging dietary index with a promising focus on the role of plant-based eating in health and environmental sustainability. So far, the role of the EAT–Lancet diet in

cardiometabolic health has only been investigated in the EPIC (European Prospective Investigation into Cancer and Nutrition)–Oxford cohort study (15), whereby high ERD scores were significantly associated with 28% decrease in ischemic heart

TABLE 3 Weighted and multivariable-adjusted HRs and bootstrapped 95% CIs of cardiovascular disease events (incidence and mortality) according to the midpoints of quintiles of usual intake of the DASH index, revised PDI, revised hPDI, ERD score, and DGAI 2020 in Canadian adults (45–80 y), CCHS–Nutrition 2004 linked to Canadian Vital Statistics—Death Database and Discharge Abstract Database, 2004–2017¹

Dietary indices	Midpoint of quintile of estimated usual dietary score, HR (95% CI)				
	1	2	3	4	5
DASH index					
Median score ²	37.62	41.80	44.93	47.95	52.44
Median score ³	37.21	41.74	45.04	48.17	52.46
Base model ⁴					
Women	1 (Reference)	0.86 (0.74, 1.00)	0.77 (0.59, 1.00)	0.67 (0.47, 0.99)	0.58 (0.34, 0.99)
Men	1 (Reference)	0.89 (0.75, 1.05)	0.81 (0.60, 1.09)	0.74 (0.48, 1.13)	0.65 (0.36, 1.19)
Multivariable-adjusted model ⁵					
Women	1 (Reference)	0.91 (0.76, 1.08)	0.85 (0.62, 1.15)	0.79 (0.52, 1.21)	0.72 (0.40, 1.31)
Men	1 (Reference)	0.87 (0.72, 1.06)	0.79 (0.57, 1.10)	0.72 (0.45, 1.14)	0.63 (0.33, 1.21)
Revised PDI					
Median score ²	34.77	37.15	38.99	40.75	43.26
Median score ³	34.13	37.07	38.99	40.94	43.53
Base model ⁴					
Women	1 (Reference)	0.97 (0.84, 1.13)	0.95 (0.73, 1.24)	0.94 (0.65, 1.35)	0.91 (0.54, 1.54)
Men	1 (Reference)	0.92 (0.79, 1.07)	0.86 (0.66, 1.12)	0.81 (0.55, 1.18)	0.74 (0.43, 1.26)
Multivariable-adjusted model ⁵					
Women	1 (Reference)	1.04 (0.86, 1.27)	1.07 (0.78, 1.48)	1.10 (0.70, 1.73)	1.14 (0.61, 2.13)
Men	1 (Reference)	0.91 (0.75, 1.12)	0.86 (0.61, 1.21)	0.81 (0.51, 1.30)	0.75 (0.39, 1.44)
Revised hPDI					
Median score ²	39.14	41.87	43.74	45.62	48.32
Median score ³	38.33	41.42	44.06	46.04	49.23
Base model ⁴					
Women	1 (Reference)	0.91 (0.80, 1.04)	0.86 (0.68, 1.07)	0.80 (0.59, 1.10)	0.73 (0.47, 1.14)
Men	1 (Reference)	0.92 (0.79, 1.07)	0.87 (0.67, 1.12)	0.82 (0.57, 1.17)	0.75 (0.45, 1.25)
Multivariable-adjusted model ⁵					
Women	1 (Reference)	0.96 (0.83, 1.11)	0.93 (0.71, 1.22)	0.91 (0.63, 1.31)	0.88 (0.52, 1.46)
Men	1 (Reference)	0.91 (0.77, 1.08)	0.84 (0.62, 1.15)	0.79 (0.52, 1.21)	0.72 (0.40, 1.30)
Revised uPDI					
Median score ²	34.68	37.37	39.25	41.13	43.87
Median score ³	33.78	36.97	38.95	41.57	44.66
Base model ⁴					
Women	1 (Reference)	1.10 (0.96, 1.25)	1.17 (0.94, 1.46)	1.25 (0.91, 1.70)	1.37 (0.88, 2.13)
Men	1 (Reference)	1.09 (0.94, 1.26)	1.15 (0.89, 1.48)	1.22 (0.85, 1.74)	1.33 (0.80, 2.21)
Multivariable-adjusted model ⁵					
Women	1 (Reference)	1.04 (0.89, 1.21)	1.07 (0.83, 1.36)	1.10 (0.76, 1.59)	1.14 (0.68, 1.91)
Men	1 (Reference)	1.10 (0.93, 1.31)	1.17 (0.88, 1.55)	1.27 (0.83, 1.94)	1.39 (0.77, 2.52)
ERD score					
Median score ²	7.10	7.34	7.53	7.71	7.94
Median score ³	7.01	7.28	7.50	7.73	8.13
Base model ⁴					
Women	1 (Reference)	0.92 (0.80, 1.07)	0.87 (0.67, 1.13)	0.82 (0.56, 1.19)	0.76 (0.46, 1.27)
Men	1 (Reference)	0.76 (0.61, 0.96)	0.62 (0.42, 0.93)	0.51 (0.29, 0.90)	0.40 (0.18, 0.87)

(Continued)

TABLE 3 (Continued)

Dietary indices	Midpoint of quintile of estimated usual dietary score, HR (95% CI)				
	1	2	3	4	5
Multivariable-adjusted model ⁵					
Women	1 (Reference)	0.91 (0.71, 1.17)	0.84 (0.54, 1.32)	0.78 (0.41, 1.50)	0.68 (0.25, 1.89)
Men	1 (Reference)	0.76 (0.57, 1.01)	0.61 (0.36, 1.01)	0.48 (0.23, 1.02)	0.32 (0.10, 1.03)
DGAI 2020					
Median score ²	6.84	7.54	8.03	8.47	9.17
Median score ³	6.77	7.55	8.06	8.55	9.20
Base model ⁴					
Women	1 (Reference)	0.91 (0.77, 1.07)	0.85 (0.64, 1.12)	0.80 (0.55, 1.17)	0.73 (0.42, 1.24)
Men	1 (Reference)	1.15 (0.96, 1.39)	1.27 (0.93, 1.74)	1.39 (0.90, 2.14)	1.60 (0.87, 2.95)
Multivariable-adjusted model ⁵					
Women	1 (Reference)	1.03 (0.85, 1.25)	1.05 (0.76, 1.44)	1.07 (0.69, 1.64)	1.09 (0.60, 1.97)
Men	1 (Reference)	1.13 (0.92, 1.38)	1.21 (0.87, 1.70)	1.31 (0.82, 2.08)	1.44 (0.76, 2.72)

¹ $n = 6771$. Weighted HRs were calculated using regression calibration (Cox proportional hazards model) and the 95% CIs calculated by bootstrapping the usual intake estimating models B = 500 times at each step. All Cox models used sex interaction to test for effect modification by sex (P -interaction < 0.0001 for all). CCHS: Canadian Community Health Survey; DASH, Dietary Approaches to Stop Hypertension; DGAI, Dietary Guidelines for Americans Adherence Index; ERD, EAT–Lancet Reference Diet; hPDI, healthful Plant-based Diet Index; PDI, Plant-based Diet Index; uPDI, unhealthful Plant-based Diet Index.

²Weighted and error-adjusted usual intake median of the diet quality index score; corresponds to base model (midpoint of quintiles).

³Weighted and error-adjusted usual intake median of the diet quality index score; corresponds to multivariable-adjusted model (midpoint of quintiles).

⁴Base model: adjusted for day of the week on which 24-h dietary recall was collected [weekday/weekend (Friday–Sunday)], sequence of dietary recall (first or second), and baseline age (continuous).

⁵Multivariable-adjusted model: adjusted for base model covariates in addition to education (less than secondary school graduation; secondary school graduation; some postsecondary; postsecondary graduation), smoking (daily/occasional smoker with $20 \leq$ cigarettes/d < 90; daily/occasional smoker with <20 cigarettes/d; former daily/occasional smoker and those who smoked a total of ≥ 100 cigarettes in lifetime; never smoked), misreporting (under-reporter; plausible reporter and over-reporter), physical activity (daily energy expenditure ≥ 3 ; $1.5 \leq$ daily energy expenditure < 3; and $0 \leq$ daily energy expenditure < 1.5), marital status (married/common-law partner; widowed/separated/divorced/single; never married), immigrant (yes/no), and alcohol consumption (none; less than once a month/once a month/2–3 times a month; once a week/2–3 times a week; 4–6 times a week/every day).

disease arguably due to the large proportion of vegetarians in the sample. Nonetheless, the global diet has largely been criticized for relying on suboptimal quantities of specific food groups, as well as for its limited applicability to countries with a high/middle sociodemographic index (52, 53). In our study, high ERD scores were associated with a nonsignificant but reduced risk of CVD incidence and mortality in both women and men, suggesting potential health benefits. Further nationally representative research is warranted to improve the inherent methodological limitations of the ERD score before its establishment as a robust plant-based dietary index in Canada.

A key novelty of our study was development and validation of the DGAI 2020, which was updated from the DGAI 2015 (16) with the release of the 2020 DGA (7). Compared to the previous version, the DGAI 2020 brings about an increase (by 0.5 servings) in the recommended intake of nuts, seeds, and soy, as well as substituting “protein foods” for a “meat and beans” subcomponent, combining all plant and animal protein into 1 category. In our study, the DGAI 2020 was non-significantly but positively associated with CVD incidence and mortality. To the best of our knowledge, the association of the DGAI with CVD risk has not been previously explored in nationally representative studies, even though observational research has confirmed positive associations between high adherence to previous versions of the DGAI and cardiovascular health (31, 51, 54, 55). A potential reason for the non-significant slightly elevated risks of CVD outcomes in the highest quintiles of the DGAI 2020 in our research could be the fact that the DGAI score does not distinguish healthy from unhealthy plant- and animal-based products as well as the revised PDI and ERD scores do. Indeed, the DGAI 2020 combines plant and animal proteins into 1 category—with a focus on meeting daily requirements rather than placing restrictions on meat intake—although replacement of as little as 3% of energy from animal sources with plant sources was recently reported to reduce CVD risk (56).

A notable strength of our study was the use of a national nutrition survey linked to health administrative databases to eliminate the challenges of cohort design (e.g., loss to follow-up, non-representative sample). Another considerable strength in our methodological approach was application of the NCI method for handling random measurement error while taking into consideration a number of confounders in a priori-defined analyses (57, 58). Furthermore, compared with previous studies, a unique feature of the present research was handling systematic error through controlling for misreporting bias (33). Despite the aforementioned strengths, our study is not without limitations. The relatively short follow-up time available in health administrative databases may have partially contributed to a lack of power to detect significant differences. Sex interaction (instead of sex stratification) was used in our regression analyses, which resulted in our inability to observe the individual effects from other lifestyle factors (model confounders). Lastly, lack of repeated dietary measurements, differences in methodology between the CCHS-Nutrition cycles, and the overall low adherence to healthy dietary patterns in the present study may have led to reduced sensitivity and specificity in detecting statistically significant differences.

In conclusion, in a nationally representative sample of Canadian adults, we confirmed the validity and reliability of the DGAI

2020 and revised PDI (but not the ERD score) as acceptable measures of diet quality. We observed no significant associations between dietary indices with CVD incidence and mortality. Nonetheless, close adherence to the dietary recommendations outlined in the 2020 DGA and the revised Plant-based Dietary pattern was associated with a higher diet quality and a lower risk of obesity. Future studies should continue exploring the potential benefits of emerging plant-based dietary patterns in relation to CVD outcomes in population-based settings, as well as addressing the lack of a uniform framework in scoring algorithms of dietary indices.

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Data Availability

Data described in the article, code book, and analytic code will be made available upon request pending application and approval (By Statistics Canada).

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