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ARTICLE

Evaluation of the Healthy Eating Food Index (HEFI)-2019 measuring adherence to Canada's Food Guide 2019 recommendations on healthy food choices[1]

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Abstract: The objective of this study was to evaluate the construct validity and reliability of the Healthy Eating Food Index-2019 (HEFI-2019), which was developed to measure adherence to Canada's Food Guide 2019 (CFG-2019) recommendations on healthy food choices. Dietary intake data from 24-hour dietary recalls in the 2015 Canadian Community Health Survey-Nutrition were used for that purpose. Multidimensionality was examined using principal component analysis. Mean scores were compared among subgroups of the population. The association between scores and energy intake was assessed using Pearson correlations. Cronbach's alpha was calculated to assess reliability. The estimated mean HEFI-2019 score (/80) was 43.1 (95% CI, 42.7 to 43.6) among Canadians aged 2 years and older. The first and 99th percentiles were 22.1 and 62.9 points. The mean HEFI-2019 score for smokers was 7.2 points lower than for non-smokers (95% CI, −8.5 to −5.9). The HEFI-2019 was weakly correlated with energy intake (r = −0.13; 95% CI, −0.20 to −0.06). The principal components analysis revealed at least 4 dimensions. Cronbach's alpha was 0.66 (95% CI, 0.63 to 0.69). Evidence of construct validity and internal consistency support the use of the HEFI-2019 to assess adherence to CFG-2019's recommendations on healthy food choices.

Novelty:

- Examination of the HEFI-2019's psychometric properties is needed prior to implementation.
- Analyses support the construct validity and internal consistency of the HEFI-2019.
- Interpretation of the total HEFI-2019 score must be accompanied by its components' scores, considering it assesses multiple dimensions of food choices.

Key words: Canada's Food Guide, Healthy Eating Food Index, HEFI-2019, nutrition survey, 24-hour dietary recalls, diet quality, validation, 2015 CCHS-Nutrition, dietary guidelines.

Résumé : L'objectif de cette étude était d'évaluer la validité conceptuelle et la fiabilité du *Healthy Eating Food Index*-2019 (« HEFI-2019 ») qui a été développé pour mesurer le respect des recommandations du Guide alimentaire canadien 2019 (GAC 2019) sur les choix alimentaires sains. Les données sur l'apport alimentaire tirées des rappels alimentaires de 24 heures de l'Enquête sur la santé dans les collectivités canadiennes-Nutrition 2015 ont été utilisées à cette fin. La multidimensionnalité a été examinée à l'aide d'une analyse en composantes principales. Les scores moyens ont été comparés entre les sous-groupes de la

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population. L'association entre les scores et l'apport énergétique a été évaluée à l'aide de corrélations de Pearson. L'alpha de Cronbach a été calculé pour évaluer la fiabilité. Le score HEFI-2019 moyen estimé (/80) était de 43,1 (IC à 95 %, 42,7 à 43,6) chez les Canadiens de 2 ans et plus. Les premier et 99e centiles étaient de 22,1 et 62,9 points. Le score HEFI-2019 moyen des fumeurs était inférieur de 7,2 points à celui des non-fumeurs (IC à 95 %, −8,5 à −5,9). Le score HEFI-2019 était faiblement corrélé à l'apport énergétique (r = −0,13; IC à 95 %, −0,20 à −0,06). L'analyse en composantes principales a révélé au moins 4 dimensions. L'alpha de Cronbach était de 0,66 (IC à 95 %, 0,63 à 0,69). Les données probantes de la validité conceptuelle et de la cohérence interne appuient l'utilisation du HEFI-2019 pour évaluer le respect des recommandations du GAC-2019 sur les choix alimentaires sains. [Traduit par la Rédaction]

Les nouveautés :

- L'examen des propriétés psychométriques de HEFI-2019 est nécessaire avant sa mise en œuvre.
- Les analyses soutiennent la validité conceptuelle et la cohérence interne de HEFI-2019.
- L'interprétation du score total HEFI-2019 doit être accompagnée des scores de ses composantes étant donné qu'il évalue plusieurs dimensions des choix alimentaires.

Mots-clés : guide alimentaire canadien, *Healthy Eating Food Index*, HEFI-2019, enquête sur la nutrition, rappels alimentaires de 24 heures, qualité de l'alimentation, validation, ESCC-Nutrition 2015, recommandations alimentaires.

Introduction

The updated Canada's Food Guide (CFG) released in 2019 includes dietary guidance both on healthy food choices ("what to eat") and healthy eating habits ("how to eat") (Health Canada 2019*b*). CFG-2019 aims to promote healthy eating and overall nutritional well-being of Canadians aged 2 years and older (Health Canada 2019*a*). Some key recommendations on healthy food choices in CFG-2019 are expressed in terms of proportions (e.g., consume plant-based protein foods more often than animal-based protein foods). These important changes compared with previous editions of CFG prompted the development of the Healthy Eating Food Index-2019 (HEFI-2019) (Brassard et al. 2022) to assess adherence to the recommendations related to healthy food choices in CFG-2019. Details regarding the development of the HEFI-2019 are presented in an accompanying paper (Brassard et al. 2022). The 10 components of the HEFI-2019 and their scoring standards were derived from key recommendations in CFG-2019 (Brassard et al. 2022; Health Canada 2019*b*). Among the 10 components, 5 are based on the intake of foods (Vegetables and fruits, Whole-grain foods, Grain foods ratio, Protein foods, Plant-based protein foods), 1 on beverages (Beverages), and 4 on nutrients (Fatty acids ratio, Saturated fats, Free sugars and Sodium).

The psychometric properties of an index measuring adherence to a given set of dietary guidelines must be verified before its use in various research settings (Kirkpatrick et al. 2019), including in population-based surveys (Kirkpatrick et al. 2018). Indeed, assessing adherence to recommendations in CFG-2019 with a validated HEFI-2019 may reduce the risk of inconsistent research findings that may impact policy decision-making and lead to confusing messages to the public. Relevant dimensions of validity applicable to the HEFI-2019 include construct validity, for example the extent to which a given index varies according to other variables known to be associated with diet quality. Reliability, i.e., the extent to which all components of an index are internally consistent (Bland and Altman, 2002; Frongillo et al. 2019), is also another important dimension of validity applicable to the HEFI-2019.

The objective of this study was therefore to evaluate the construct validity and reliability in terms of internal consistency of the HEFI-2019.

Methods

Study design and participants

Analyses were performed using data from the most recent national survey capturing food consumption of Canadians, the 2015 CCHS-Nutrition (Health Canada 2017). The 2015 CCHS-Nutrition is a nationally representative survey of individuals aged 1 year and older living in private dwellings in the 10 Canadian provinces. Full-time members of the Canadian Forces and individuals living in the Territories, on reserves, in remote areas, and in institutions were not included. Data were collected between January 1st to December 31, 2015. Since the CFG-2019 targets the Canadian population aged 2 years and older, all respondents younger than 2 years (n = 367) were excluded from the present analyses. Respondents reporting no consumption (i.e., zero energy intake) were also excluded (n = 8), yielding a final sample of 20 103 respondents. Of note, pregnant and lactating women (less than 1.5% of all participants in the CCHS-Nutrition 2015) were included. Analyses of the 2015 CCHS-Nutrition data were based on the public use microdata files (PUMF) obtained from Statistics Canada. Secondary analyses of data from the 2015 CCHS-Nutrition conducted by Statistics Canada do not require additional ethics approval.

Dietary assessment in the CCHS 2015-Nutrition

Dietary intakes of respondents were assessed using the 24-hour recall method and following a structure consistent with the Automated Multiple Pass Method (Health Canada 2017). Trained interviewers conducted computer-assisted interviews in person for 96% of the first 24-hour recalls and by phone for the subset of respondents (37%) who completed a second 24-hour recall. For children aged 6 years or younger, the 24-hour recall interviews were answered by a parent or guardian (Health Canada 2017). For children aged 6 to 11 years, the 24-hour recall interviews were conducted with the assistance of the parent. All respondents aged 12 years and older were interviewed directly. A food booklet was provided to respondents to facilitate portion size estimation of foods and beverages in plates, bowls, glasses and mugs (Health Canada 2017). Reported dietary intakes measured via 24-hour recall were first classified according to the food categories used to calculate the various components of the HEFI-2019 and were then summed per respondent for each 24-hour dietary recall available (Brassard et al. 2022). Reference amounts (RAs), expressed in grams, were used as the reference metric to assess intakes of foods. RAs are regulated amounts that reflect the amount of food typically consumed in 1 sitting and are developed and maintained mainly for nutrition labelling purposes (Health Canada 2016). Nutrient intakes were computed using the Canadian Nutrient File 2015 (Health Canada 2018). Data on RAs were obtained from the Government of Canada website (Health Canada 2016) and data on free sugars were obtained from Health Canada's estimation (Rana et al. 2021). Free sugars are monosaccharides and disaccharides added to foods, sugars naturally present in honey, syrups, fruit juices and fruit juice concentrates, and sugars from foods whose structure has been broken down (e.g., fruit or vegetable juices, purées or pastes, extracts and artificial flavourings, alcoholic drinks) (Rana et al. 2021).

HEFI-2019

Complete details regarding the development of the HEFI-2019, assignment of scores and alignment with CFG-2019 are provided

Table 1. Healthy Eating Food Index (HEFI)-2019 components, points and standards for scoring.

#	Component name	Measurement (ratio)	Maximum points	Unit	Standard for minimum score	Standard for maximum score
1	Vegetables and fruits	Total vegetables and fruits[a] / Total foods[b]	20	RA/RA	No vegetables and no fruits	≥0.50
2	Whole-grain foods	Total whole-grain foods[c] / Total foods[b]	5	RA/RA	No whole-grain foods	≥0.25
3	Grain foods ratio	Total whole-grain foods[c] / Total grain foods[d]	5	RA/RA	No whole-grain foods	1.0
4	Protein foods	Total protein foods[e] / Total foods[b]	5	RA/RA	No protein foods	≥0.25
5	Plant-based protein foods	Plant-based protein foods[f] / Total protein foods[e]	5	RA/RA	No plant-based protein foods	>0.50
6	Beverages	(Plain water including carbonated + unsweetened beverages)[g] / Total beverages[h]	10	g/g	No water and no unsweetened beverages	1.0
7	Fatty acids ratio	(Mono- + polyunsaturated fat) / Total saturated fat	5	g/g	≤1.1[i]	≥2.6[j]
8	Saturated fats	Total saturated fat / energy	5	%E (kcal/kcal)	≥15%E[k]	<10%E
9	Free sugars	Total free sugars / energy	10	%E (kcal/kcal)	≥20%E[k]	<10%E
10	Sodium	Total sodium / energy	10	mg/kcal	≥2.0[k]	<0.9[l]

Note: CCHS, Canadian Community Health Survey; CDRR, Chronic Disease Risk Reduction; CFG-2019, Canada's Food Guide 2019; RA, Reference Amounts (amount of food usually eaten by an individual at 1 sitting, defined as the Table of Reference Amounts in Health Canada 2016); %E, percent of total energy.

[a]All vegetables and fruits regardless of saturated fat, sodium or free sugar content; excludes fruit juice (i.e., considered as sugary drinks in CFG-2019).

[b]Includes all foods consumed as well as beverages considered in protein foods (i.e., unsweetened milk and unsweetened plant-based beverages that contain protein); excludes all other beverages as well as solid fats, oils and spreads and culinary ingredients (e.g., spices and baking soda).

[c]Foods where the first ingredient is either whole grains or whole wheat, regardless of saturated fat, sodium or free sugar content.

[d]Foods where the first ingredient is grains (whole or not) regardless of saturated fat, sodium or free sugar content.

[e]All protein foods regardless of fat, sodium or sugars content; excludes processed meats (i.e., not considered protein foods in CFG-2019) and sweetened milks (i.e., considered as sugary drinks in CFG-2019).

[f]All plant-based protein foods, regardless of saturated fat, sodium or free sugar content.

[g]Unsweetened beverages include (unsweetened) coffee and tea, (unsweetened) milk and plant-based beverages.

[h]Total beverages include water (plain or carbonated), coffee, tea, milk and plant-based beverages, fruit and vegetable juices, alcoholic drinks, artificially sweetened beverages and sugary drinks.

[i]Approximately the 15th percentile of intake based on data (single 24-hour recall) in Canadians from the 2015 CCHS-Nutrition.

[j]Corresponds to the 1st percentile of unsaturated to saturated fats ratios among simulated diets developed to be fully consistent with all recommendations in CFG-2019.

[k]Approximately the 85th percentile of intake based on data (single 24-hour recall) in Canadians from the 2015 CCHS-Nutrition.

[l]Standard for maximum points based on the CDRR for 14+ years (i.e., 2300 mg) over the 90th percentile of usual energy intakes in respondents aged 2 years and older from the 2015 CCHS-Nutrition (i.e., approximately 2600 kcal, see Brassard et al. 2022 for details).

and discussed in an accompanying article (Brassard et al. 2022). Briefly, the index comprises 10 components named Vegetables and fruits, Whole-grain foods, Grain foods ratio, Protein foods, Plant-based protein foods, Beverages, Fatty acids ratio, Saturated fats, Free sugars and Sodium. Each component relates to key recommendations identified in CFG-2019. Scoring standards were taken directly from targets proposed in CFG-2019 (e.g., Saturated fats, Free sugars and Sodium components) or derived from the guidelines based on consumption data and expert judgement (Brassard et al. 2022). A list of HEFI-2019 components, points and scoring standards is presented in Table 1. As discussed in the accompanying paper (Brassard et al. 2022), vegetables and fruits are considered a key indicator of diet quality (Garriguet 2009) and an important component of healthy dietary patterns (Health Canada 2019*c*). Thus, this component was weighted more heavily (20 points) than all other components (up to 10 points; Table 1). A maximum of 5 points was attributed to pair of components related to a particular recommendation or closely linked recommendations (e.g., Protein foods and Plant-based protein foods), ensuring that the overall weight of such combinations of components would not exceed 10 points. Once scores from the 10 components are summed, the index has a maximum of 80 points and reflects adherence to recommendations on healthy food choices in CFG-2019.

Strategies to evaluate psychometric properties of the HEFI-2019

A priori defined analyses used to evaluate the construct validity and reliability (internal consistency) of the HEFI-2019 are presented in Table 2. These analyses are consistent with the ones performed for the evaluation of the 3 latest versions of the US Healthy Eating Index (HEI) (Guenther et al. 2008, 2014; Reedy et al. 2018).

Statistical analyses

All statistical analyses used sampling weights provided by Statistics Canada to generate results that are generalizable to the Canadian population. Bootstrap weights, also provided by Statistics Canada, were used to estimate variances via the Balanced Repeated Replication method. Survey-specific procedures were used when applicable (i.e., PROC SURVEYREG). Analyses were performed in SAS Studio v3.8 (SAS Institute) and R v3.6.2 (R Foundation for Statistical Computing).

Task 1: Variability among individuals

First, distributions of usual dietary intakes for each of the 10 components of the HEFI-2019 were estimated using the National Cancer Institute (NCI)'s multivariate Markov Chain Monte Carlo method (Zhang et al. 2011). This method permits simultaneous estimation of distributions of usual intakes for multiple dietary components that are skewed, correlated with each other and measured with error (within-individual random error). The method also accounts for systematic differences in intakes according to day of the week (i.e., weekend vs. weekdays) and sequence of recalls (i.e., first vs. second 24-hour recall). Since within-individual random dietary intake variations are expected to differ across life stages

Table 2. Summary of a priori defined strategies to evaluate the construct validity and reliability of the HEFI-2019.

Task	Question	Rationale	Strategy
Construct validity			
1	Does the HEFI-2019 vary sufficiently among individuals?	Sufficient score variability among individuals is required to discriminate a higher or lower degree of adherence to CFG-2019	Estimate the distribution of HEFI-2019 scores based on usual dietary intakes
2	Does the HEFI-2019 differentiate groups with known differences in diet quality?	An index reflecting adherence to CFG-2019 is expected to produce scores that differ between groups with known differences in diet quality	Compare mean HEFI-2019 scores between males vs. females; 50–70 y vs. 19–30 y adults; and smokers vs. non-smokers
3	Is the HEFI-2019 consistent with other previously validated diet quality indices?	An index reflecting adherence to CFG-2019 is expected to be consistent with other indices of diet quality	Examine the association between the HEFI-2019 and the US HEI-2015 scores
4	Is the HEFI-2019 independent of total energy intake (amount of food consumed)?	An index reflecting adherence to CFG-2019 should be mostly independent of energy intake, so that the index reflects the quality and not quantity of foods consumed	Examine associations between the HEFI-2019 score based on usual dietary intakes and usual energy intake
5	Is the HEFI-2019 multidimensional?	An index reflecting adherence to CFG-2019 assesses multiple dimensions of food choices and, consequently, should not depend on only 1 component	Conduct principal component analysis on the HEFI-2019 score based on usual dietary intakes
Reliability			
6	Is the HEFI-2019 internally consistent?	To be useful as an overall metric, the components of the index should be in large part consistent with one another	Calculate Cronbach's alpha for the HEFI-2019
7			Estimate the association between each component's score and the residual HEFI-2019 score (total HEFI-2019 minus the component assessed)

Note: CFG-2019, Canada's Food Guide-2019; HEFI-2019, Healthy Eating Food Index-2019; US HEI-2015, United States Healthy Eating Index 2015.

(Herrick et al. 2018), the models included stratification according to age and sex to better reflect these variations. The 3 strata used were children and adolescents aged 2–18 years (both sexes combined), males aged 19 years and older, and females aged 19 years and older. To obtain estimates of usual intakes for relevant age and sex groups, the models' covariates were age categorized according to Dietary Reference Intake (DRI) age groups (Institute of Medicine (US) Subcommittee on Interpretation and Uses of Dietary Reference Intakes; Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes 2000) and sex (only for 2–18 years). An indicator variable for sequence (1st or 2nd recall) was used to account for potential sequence effect, and an indicator variable for weekend days (Friday, Saturday, Sunday) was used to balance the proportion of weekend and weekdays. When applying NCI methods, the use of stratification (i.e., both sexes aged 2–18 years, males aged 19 years and older, females aged 19 years and older) allows the measurement error model parameters to vary according to these strata, while covariates (i.e., DRI age groups) allows to output distributions specific to those age groups. Whole-grain foods, plant-based protein foods and some beverages (sugary drinks, artificially sweetened beverages, vegetable and fruit juices, sweetened milk and plant-based beverages, alcohol, unsweetened milk and unsweetened soy beverages) were considered episodically consumed when applying the NCI's multivariate method that generates usual intake data. All the remaining foods and nutrients were considered to be consumed daily by most persons. The method requires that food and beverages categories be mutually exclusive (Zhang et al. 2011). For example, when considering food categories related to the Grain foods ratio component, it is necessary to separate total grains into 2 different food categories: whole grains and non-whole grains. Usual intakes were generated for a pre-specified number of pseudo-individuals (i.e., 500 simulations per survey respondent) during the Monte Carlo simulation step. Estimated usual intakes among pseudo-individuals within each modelling stratum (i.e., children and adolescents aged 2–18 years, males aged 19 years and older, and females aged 19 years and older) were pooled. Of note, all participants are considered when estimating distributions of intakes using the NCI's multivariate method, regardless of whether they completed a single or two 24-hour recalls.

Second, the HEFI-2019 scoring algorithm was applied to the estimated usual intakes among pseudo-individuals to estimate total scores and component scores. Third, the mean and percentiles of total HEFI-2019 and component scores were estimated in the overall sample and in specified subgroups. Fourth, steps 1 to 3 were repeated 500 times with bootstrap weights to generate standard errors and 95% CI. The convergence of bootstrap standard errors and the normality of bootstrap estimates distribution were confirmed using graphical methods.

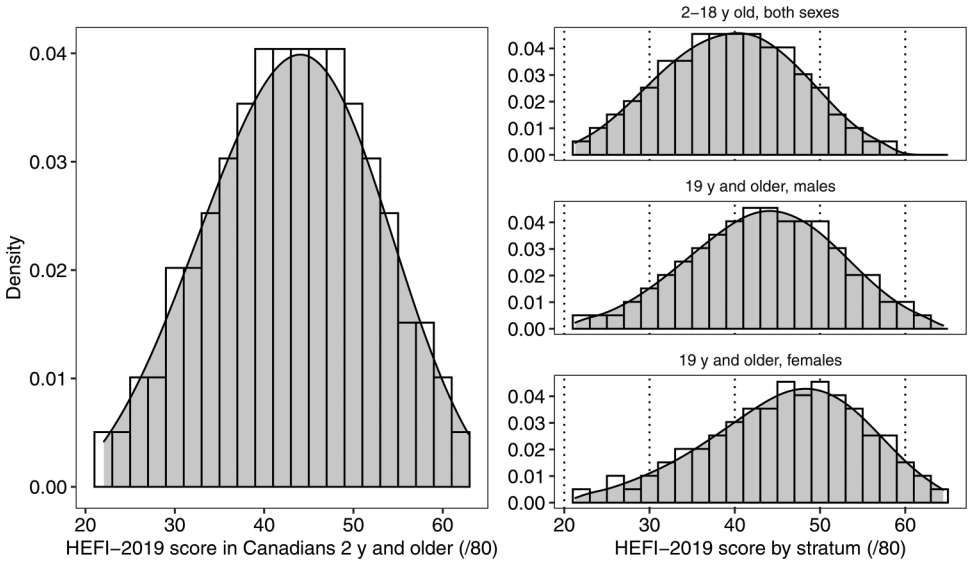
Task 2: Expected differences in HEFI-2019 between specific groups

Mean HEFI-2019 scores for subgroups with expected differences in diet quality (sex, age and smoking status (Chaltiel et al. 2019; Chiuve et al. 2012; Garriguet 2009; Reedy et al. 2018) were estimated using the population ratio method (Freedman et al. 2008). This is an appropriate method when comparing group means (Freedman et al. 2008; National Cancer Institute 2020), while also being much less computationally intensive than the NCI's multivariate method.

Task 3: Associations with the HEI-2015

We tested the hypothesis that the HEFI-2019 score is strongly correlated with the US HEI-2015 score (Krebs-Smith et al. 2018; Reedy et al. 2018), since both scores are intended to reflect overall diet quality. For this task, HEFI-2019 and US HEI-2015 scores were calculated for each respondent based on the first 24-hour recall. The relationship between the HEI-2015 and the HEFI-2019 was examined using Pearson correlation as well as linear regression with a restricted cubic spline transformation of the HEFI-2019 score to account for potential non-linearity (Harrell 2015). Quantiles

Fig. 1. Estimated distribution of total HEFI-2019 scores based on usual dietary intakes in Canadians aged 2 years and older from the 2015 CCHS-Nutrition. Usual intakes were estimated using the National Cancer Institute's multivariate method (see Methods section). The histogram bins each represent 2 points on the total score scale and do not accurately reflect the proportion of participants at a given score value. See Tables A2 and A3 in Appendix A for exact percentile values. CCHS, Canadian Community Health Survey; CFG-2019, Canada's Food Guide 2019; HEFI-2019, Healthy Eating Food Index-2019.



for knots (percentiles 5, 27.5, 72.5, 95) were selected a priori based on common placement to ensure enough data within each interval (Harrell 2015).

Task 4: Association with energy intake

The association between energy intake and HEFI-2019 scores was assessed using univariable linear regression and Pearson correlation based on dietary intake data modelled with the NCI's multivariate method to estimate usual intakes.

Task 5: Multidimensionality

Principal component analysis was used to assess multidimensionality of the HEFI-2019 based on the 10 components of the index and based on usual dietary intake data obtained with the NCI's multivariate method, as described under Task 1. The eigenvalues and eigenvectors of the principal component analysis solution were assessed to confirm multidimensionality, i.e., that the variance of the HEFI-2019 scores was not explained by only 1 of its components. The scree plot was used to visually confirm this finding.

Tasks 6 and 7: Internal consistency

Internal consistency (reliability) of the HEFI-2019 was first examined using Cronbach's alpha. The association between each component score and the residual HEFI-2019 score, i.e., total score minus the score for the component assessed, was also examined using Pearson correlations. Usual dietary intake data modelled with the NCI multivariate method were used for Tasks 6 and 7.

A posteriori defined task related to assessment of construct validity

Hypothetical food intake based on recipes developed by Health Canada to reflect CFG recommendations should yield high HEFI-2019 scores, thereby further demonstrating construct validity. To test this hypothesis, 3 hypothetical menus were built using recipes randomly selected from the recipes suggested for breakfast, lunch/dinner and snacks listed on CFG-2019 website (Health Canada 2019*b*). Each menu included 3 main meals and 1 snack (Table A1). To ensure that menus reflected plausible energy intakes, they were each standardized to 1800 kcal, the median energy intake of adults aged 19 years and older from the 2015 CCHS-Nutrition. Food, and nutrient composition of the 3 menus were averaged before calculation of the HEFI-2019.

Results

Variability among individuals

The distributions of HEFI-2019 scores based on usual dietary intakes (on a scale up to 80 points) and component scores in Canadians aged 2 years and older are presented in Figs. 1 and 2, and Tables A2–A4 and Fig. A1 in Appendix A. Based on usual dietary intake data, the estimated mean HEFI-2019 score was 43.1 points (95% CI, 42.7 to 43.6), and the median was 43.4 points (95% CI, 42.9 to 43.9) with a range from 22.1 (percentile 1) to 62.9 points (percentile 99; Fig. 1). Among component scores, relatively important "ceiling" effects, i.e., a large proportion of respondents receiving maximum points, were noted for Protein foods, Saturated fats and Free sugars (Figs. 2 and A1). The mean HEFI-2019 scores were the lowest in Canadians aged 2–18 years (39.5 points) and highest in females aged 19 years and older (46.0 points; Table A3). The distributions of HEFI-2019 score are also presented by Dietary Reference Intake groups in Table A4.

Expected differences in mean HEFI-2019 scores among specific groups

Table 3 presents the mean total HEFI-2019 scores and component scores among subgroups of individuals aged 19 years and older expected a priori to show differences in HEFI-2019. The mean HEFI-2019 score was 3.1 points higher in females than in males (95% CI, 2.0 to 4.1), largely due to higher scores for the Vegetables and fruits and Beverages components. The mean HEFI-2019 score among Canadians aged 50 to 70 years was 6.5 points higher than among Canadians aged 19 to 30 years (95% CI, 5.0 to 8.1). The HEFI-2019 score among smokers was 7.2 points lower than among non-smokers (95% CI, –8.5 to –5.9).

Association with the US Healthy Eating Index-2015

Figure 3 depicts the strong linear association between the Healthy Eating Index-2015 and the HEFI-2019 scores, with a Pearson correlation coefficient of $r = 0.79$ and an $r^2 = 0.62$.

Fig. 2. Estimated distribution of HEFI-2019 component scores based on usual dietary intakes in Canadians aged 2 years and older from the 2015 CCHS-Nutrition. Usual intakes were estimated using the National Cancer Institute's multivariate method (see Methods section). The histogram bins represent 1 point and reflect approximately the proportion of participants at a given score plus or minus half a point. For example, 41% of Canadians had 9.5 points or more for the Free sugars component. See Table A2 in Appendix A for exact percentile values. CCHS, Canadian Community Health Survey; CFG-2019, Canada's Food Guide 2019; HEFI-2019, Healthy Eating Food Index-2019.

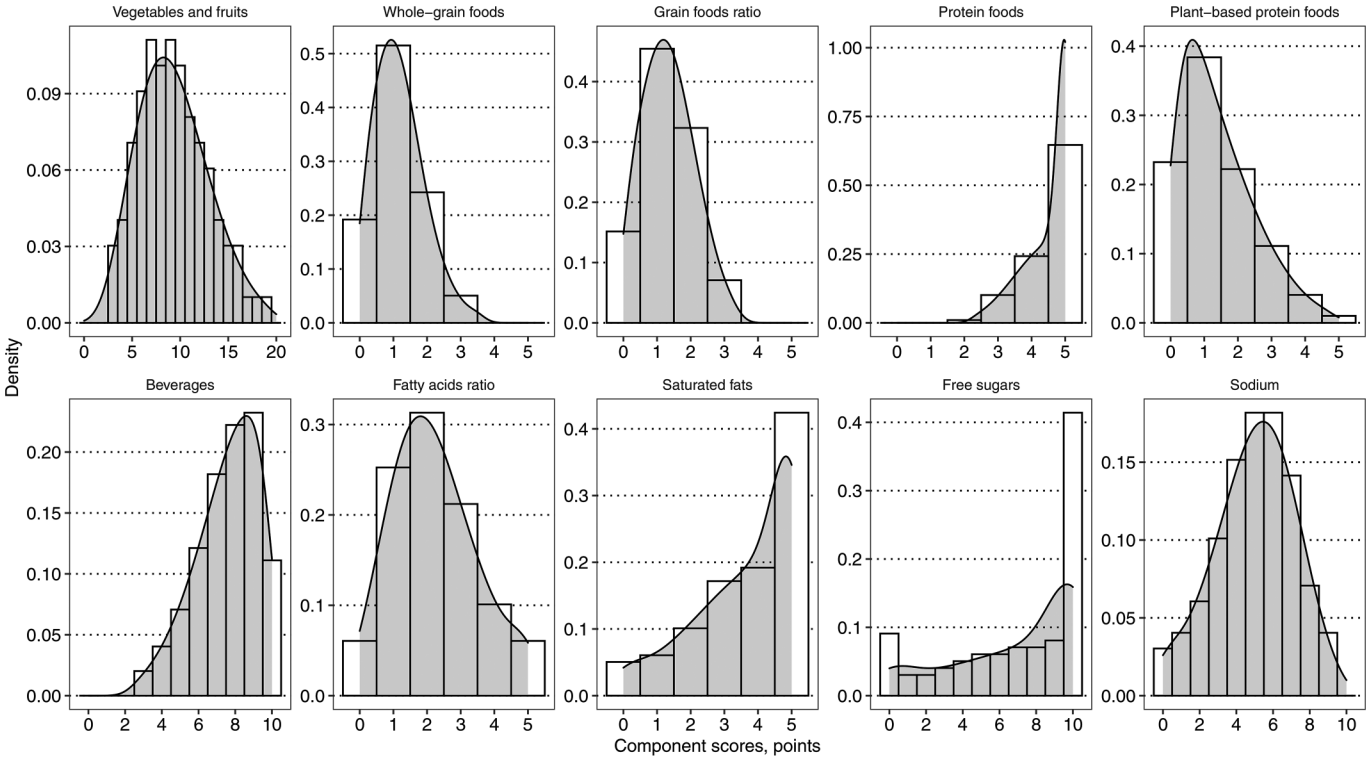


Table 3. Estimated mean HEFI-2019 scores in Canadians aged 19 years and older, by sex, by select age groups and smoking status, based on data from the 2015 CCHS-Nutrition.

	Sex			Age groups			Smoking status		
Component	Males	Females	Difference	19–30 y	50–70 y	Difference	Non-smokers	Smokers	Difference
Vegetables and fruits, /20	8.8 (0.2)	10.8 (0.2)	2.0 (1.6,2.4)	8.0 (0.3)	10.4 (0.2)	2.4 (1.8,3.0)	10.1 (0.1)	7.8 (0.2)	−2.3 (−2.8,−1.8)
Whole-grain foods, /5	1.1 (0.0)	1.2 (0.0)	0.0 (−0.1,0.1)	1.0 (0.1)	1.2 (0.1)	0.2 (0.0,0.3)	1.2 (0.0)	0.8 (0.0)	−0.4 (−0.5,−0.3)
Grain foods ratio, /5	1.4 (0.0)	1.5 (0.0)	0.1 (0.0,0.2)	1.3 (0.1)	1.6 (0.1)	0.4 (0.2,0.5)	1.5 (0.0)	1.1 (0.1)	−0.5 (−0.6,−0.3)
Protein foods, /5	5.0 (0.0)	4.9 (0.1)	−0.1 (−0.2,0.0)	5.0 (0.0)	4.8 (0.1)	−0.2 (−0.3,−0.0)	5.0 (0.0)	4.9 (0.1)	−0.1 (−0.3,0.1)
Plant-based protein foods, /5	1.7 (0.1)	1.7 (0.1)	0.0 (−0.2,0.2)	1.4 (0.2)	1.7 (0.1)	0.3 (−0.1,0.7)	1.8 (0.1)	1.3 (0.1)	−0.4 (−0.7,−0.2)
Beverages, /10	7.3 (0.1)	8.3 (0.0)	1.0 (0.8,1.1)	7.3 (0.1)	7.9 (0.1)	0.5 (0.3,0.8)	7.9 (0.0)	7.2 (0.1)	−0.7 (−1.0,−0.5)
Fatty acids ratio, /5	2.4 (0.1)	2.2 (0.1)	−0.2 (−0.3,−0.0)	2.2 (0.1)	2.5 (0.1)	0.3 (0.0,0.5)	2.4 (0.0)	2.2 (0.1)	−0.2 (−0.4,−0.0)
Saturated fats, /5	4.1 (0.1)	4.1 (0.1)	−0.1 (−0.3,0.2)	3.9 (0.1)	4.3 (0.1)	0.4 (0.0,0.7)	4.2 (0.1)	3.8 (0.1)	−0.4 (−0.7,−0.1)
Free sugars, /10	8.6 (0.2)	8.7 (0.2)	0.0 (−0.5,0.6)	7.2 (0.4)	9.3 (0.2)	2.1 (1.3,2.9)	9.0 (0.1)	7.1 (0.4)	−1.9 (−2.6,−1.1)
Sodium, /10	4.9 (0.1)	5.1 (0.1)	0.2 (−0.1,0.5)	4.9 (0.2)	5.2 (0.1)	0.2 (−0.2,0.7)	5.0 (0.1)	4.7 (0.2)	−0.3 (−0.7,0.1)
Total score, /80	45.3 (0.4)	48.4 (0.4)	3.1 (2.0,4.1)	42.3 (0.7)	48.9 (0.5)	6.5 (5.0,8.1)	48.1 (0.3)	40.9 (0.6)	−7.2 (−8.5,−5.9)

Note: Values are mean (SE) or mean difference (95% CI) between groups. Only individuals aged 19 years and older were considered for this comparison. Differences in mean HEFI-2019 for these subgroups were expected a priori based on previous literature (Chaltiel et al. 2019; Chiuve et al. 2012; Garriguet 2009; Reedy et al. 2018). Means were calculated using the population ratio method as opposed to using usual dietary intake data modelled with the NCI multivariate method. Standard errors and 95% CI were estimated using 500 bootstrap weight replicates. CCHS, Canadian Community Healthy Survey; CI, confidence interval; HEFI-2019, Healthy Eating Food Index-2019.

Association with energy intake

The estimated Pearson correlation between the HEFI-2019 score and total energy intake was −0.13 (95% CI, −0.20 to −0.06; Table 4). The estimated Pearson correlations between each component score and energy intake based on usual dietary intakes are also presented in Table 4. The Sodium component showed the strongest positive correlation ($r = 0.23$) while Beverages showed the strongest inverse correlation ($r = -0.28$) with energy intake.

Multidimensionality

The scree plot from the principal component analysis is presented in Fig. A2 of Appendix A. Scores from the first 4 linear combinations of HEFI-2019 components (i.e., principal component vectors) accounted for more than two-thirds of the total HEFI-2019 variance (69%). Figure A3 presents the eigenvectors associated with the first 4 principal components, based on usual dietary intakes. For example, Vegetables and fruits, Grain foods ratio, and Plant-

Fig. 3. Association between the total HEFI-2019 and the US HEI-2015 scores in Canadians aged 2 years and older from the 2015 CCHS-Nutrition. For illustrative purposes, values shown in the figure were restricted to percentiles 1 to 99 of the distribution of both indices and data points are from a random subset of approximately 5% of respondents selected proportionally to sampling weights. Both scores used in this analysis were not corrected for within-individual random errors. CCHS, Canadian Community Health Survey; HEFI-2019, Healthy Eating Food Index 2019; US HEI-2015, United States Healthy Eating Index 2015.

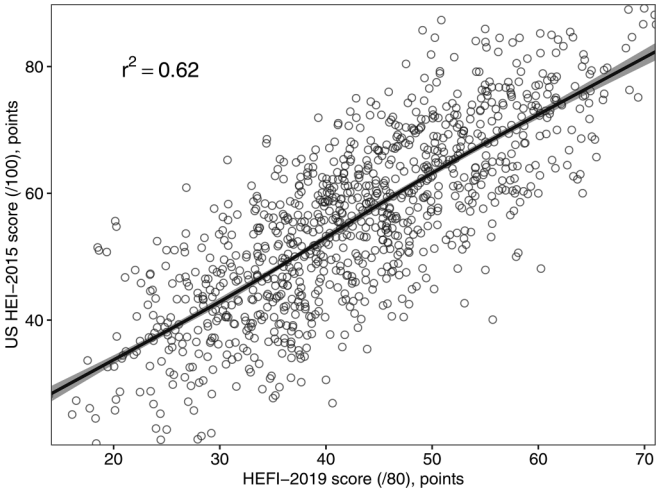


Table 4. Estimated Pearson correlation coefficients between the HEFI-2019 and usual energy intake in Canadians aged 2 years and older, based on data from the 2015 CCHS-Nutrition.

Component	Correlation coefficient with energy intake	95% CI	
		Lower	Upper
Vegetables and fruits	−0.24	−0.31	−0.16
Whole-grain foods	−0.00	−0.10	0.09
Grain foods ratio	0.07	−0.03	0.16
Protein foods	0.01	−0.08	0.11
Plant-based protein foods	0.10	−0.01	0.22
Beverages	−0.28	−0.34	−0.22
Fatty acids ratio	−0.03	−0.11	0.05
Saturated fats	−0.06	−0.15	0.02
Free sugars	−0.12	−0.19	−0.05
Sodium	0.23	0.14	0.31
Total HEFI-2019	−0.13	−0.20	−0.06

Note: The HEFI-2019 was calculated based on usual dietary intakes modelled using the National Cancer Institute's multivariate method (see Methods section). CCHS, Canadian Community Healthy Survey; CFG-2019, Canada's Food Guide-2019; CI, confidence interval; HEFI-2019, Healthy Eating Food Index-2019.

based protein foods were the 3 HEFI-2019 components contributing the most to the principal component #1. While the principal component #1 accounted for the largest proportion of the total HEFI-2019 variance (27%; Fig. A2), the principal components #2, 3 and 4 provided further information on the HEFI-2019 scores pattern among Canadians (Figs. A2, A3), consistent with the multidimensional nature of dietary intake.

Internal consistency

The standardized Cronbach's alpha of the HEFI-2019 was 0.66 (95% CI, 0.63 to 0.69). The estimated Pearson correlations between scores of each component and the residual HEFI-2019 score (i.e., total HEFI-2019 minus the score of the component being assessed), both based on usual dietary intakes, are presented in Table 5. The correlations between each component score and the residual HEFI-2019 score ranged from 0.02 (Sodium) to 0.51 (Vegetables and fruits).

Further analysis of construct validity

Three days of randomly selected recipes designed to meet CFG recommendations and proposed on Health Canada's Web site yielded a HEFI-2019 score of 67.1 points, which is 4.2 points higher than the 99th percentile of the total HEFI-2019 score for Canadians aged 2 years and older based on data from the 2015 CCHS-Nutrition. The components scores were the lowest for Plant-based protein foods (0.7/5 points), Fatty acids ratio (1.7/5 points), and Whole-grain foods (4/5 points) and perfect for Grain foods ratio, Protein foods, Beverages, Saturated fats, and Free sugars.

Discussion

Our objective was to evaluate the construct validity and reliability of the HEFI-2019, an index developed to assess adherence to recommendations on healthy food choices in CFG-2019. The HEFI-2019 reveals sufficient variations among Canadians; captures expected differences in diet quality related to sex, age and smoking status; correlates strongly with the US HEI-2015; and captures multiple dimensions of diet quality as defined by CFG-2019. The components of the HEFI-2019 are mostly consistent with one another. Of note, the HEFI-2019 score correlates only weakly and inversely with energy intake. The internal consistency of the HEFI-2019 is only slightly less than satisfactory according to the common interpretation of Cronbach's alpha (Bland and Altman 1997), but this was expected to a large extent considering the multidimensionality of the index. Overall, these analyses of construct validity and reliability support the use of the HEFI-2019 as a metric measuring adherence to Canadian-specific recommendations on healthy food choices.

Construct validity was supported by appreciable variability in HEFI-2019 scores among Canadians based on data from 2015 CCHS-Nutrition. Of note, the distributions of the scores for Protein foods, Saturated fats and Free sugars components were skewed towards maximum scores mostly due the fact that an important proportion of the population meets the recommendations regarding these foods and nutrients (Brassard et al. 2022). Inversely, the distributions of the scores for Whole-grain foods, Grain foods ratio and Plant-based protein foods components were skewed towards lower scores. Nonetheless, variability of total HEFI-2019 scores among Canadians was sufficient to capture expected differences in diet quality between specific groups based on sex, age and smoking status (Chaltiel et al. 2019; Chiuve et al. 2012; Garriguet 2009; Reedy et al. 2018). Future research is needed to determine a target HEFI-2019 score above which individual or population diets meet the majority of CFG recommendations on food choices to be considered as being healthy or of high quality.

Total HEFI-2019 score was strongly correlated with the US HEI-2015 score, which reflects adherence to the 2015 Dietary Guidelines for Americans. This finding also supports construct validity considering that both indices reflect adherence to sets of guidelines that are based on a similar body of evidence (Health Canada 2019*c*). In addition, variability among individuals for the HEFI-2019 (22.1 to 62.9 points for the 1st and 99th percentile, respectively) was similar that of the US HEI-2015, which also supports construct validity.

The HEFI-2019 score was only weakly and inversely associated with energy intake (r = –0.13). This is not entirely unexpected, considering that the Beverages and Vegetables and fruits components' scores also show modest but inverse correlations with energy intake (r = –0.28 and –0.24, respectively), largely due to the fact that the numerators and denominators of both components have a low and high energy density, respectively. The US HEI-2015 scores are not associated with energy intake (Reedy et al. 2018) because all components of the HEI-2015 are calculated as ratios

Table 5. Estimated Pearson correlation coefficients of component scores and residual HEFI-2019 score in Canadians aged 2 years and older, based on data from the 2015 CCHS-Nutrition.

Component	Vegetables and fruits	Whole-grain foods	Grain foods ratio	Protein foods	Plant-protein foods	Beverages	Fatty acids ratio	Saturated fats	Free sugars	Sodium
Vegetables and fruits	1.00	—	—	—	—	—	—	—	—	—
Whole-grain foods	0.15	1.00	—	—	—	—	—	—	—	—
Grain foods ratio	0.32	0.83	1.00	—	—	—	—	—	—	—
Protein foods	0.03	0.05	0.04	1.00	—	—	—	—	—	—
Plant-based protein foods	0.33	0.17	0.22	0.01	1.00	—	—	—	—	—
Beverages	0.27	0.15	0.18	0.06	0.20	1.00	—	—	—	—
Fatty acids ratio	0.24	0.02	0.05	0.02	0.41	0.10	1.00	—	—	—
Saturated fats	0.29	0.16	0.11	0.02	0.20	−0.09	0.60	1.00	—	—
Free sugars	0.34	0.10	0.14	0.24	0.19	0.49	0.27	0.13	1.00	—
Sodium	0.16	0.07	0.12	0.06	0.11	−0.18	−0.07	0.13	−0.15	1.00
Residual HEFI-2019[a]	0.51	0.27	0.38	0.14	0.41	0.33	0.37	0.33	0.39	0.02

Note: The HEFI-2019 was calculated based on usual dietary intakes modelled using the National Cancer Institute's multivariate method (see Methods section). CCHS, Canadian Community Healthy Survey; HEFI-2019, Healthy Eating Food Index-2019.

[a]For the correlation between a given component score and the residual HEFI-2019, the HEFI-2019 corresponded to the total HEFI-2019 from which points from the component being assessed were subtracted.

over total energy intake. Although the inverse association between HEFI-2019 scores and energy intake is weak and possibly of little to no concern, users of the index should be mindful of this. It is recommended that energy intake be considered when comparing and interpreting trends over time or differences among groups when using the HEFI-2019.

The internal consistency of the HEFI-2019 (0.66) almost achieved the Cronbach alpha minimal acceptable value for reliability of 0.70. The multidimensional nature of the HEFI-2019 and the relatively small number of components, the fact that it was calculated based on dietary intake data from a heterogeneous population (Canadians aged 2 years and older) and that components were identified a priori and included irrespective of their contribution to the final index explain why the internal consistency of the HEFI-2019 was not higher (Kirkpatrick et al. 2019; Reedy et al. 2018). The Protein foods and Sodium components' scores showed the weakest correlation with the residual HEFI-2019 score, thus contributing to a lower internal consistency. It is interesting to note that the Cronbach alpha of the US HEI-2015 (0.67) based on NHANES 2011–2012 (Reedy et al. 2018) is the same as the HEFI-2019. Although generally preferable, a high degree of internal consistency was not defined a priori as a requirement when developing the HEFI-2019. Users of the HEFI-2019 must be mindful that some individual components are more consistent with one another than others, with the global construct reflecting adherence to recommendations on healthy food choices in CFG-2019. Finally, the HEFI-2019 scores could be modified in the future to be more discriminant, especially regarding components' scores with important floor or ceiling effects. However, it is stressed that modified scoring standards of such components may or may not reflect adherence to specific recommendations in CFG-2019 as per the original purpose of the HEFI-2019 (Brassard et al. 2022).

The degree of adherence of Canadians' eating patterns to the 2019 CFG as measured by the HEFI-2019 was previously unknown. The estimated mean HEFI-2019 among Canadians in 2015 was 43.1 (/80) points (or 53.9%), reflecting a relatively low degree of adherence. Although this is slightly lower than the average Canadian HEI-2007 (58.8 points out of 100) of Canadians surveyed in 2004 (Garriguet 2009), these 2 scores cannot be compared as they measure adherence to different sets of dietary guidelines. Children showed the lowest degree of adherence to recommendations on healthy food choices in CFG-2019 compared with other age and sex groups. In the present analysis, Canadians aged 2–18 years had particularly low scores for the Fatty acids ratio, Plant-based protein foods and Free sugars components (Table A3), which is consistent with data in the CCHS-2015 (Hack et al. 2021) among children and adolescents aged 2–18 years. Studies from the United Kingdom (Gibson et al. 2016) and Australia (Louie et al. 2016) also reported that intakes of free sugars among children and adolescents were above the World Health Organization's recommendation of 10% of total energy intake. Finally, the 99th percentile of the HEFI-2019 score among Canadians was 62.9 on a total of 80 points, i.e., 78.6%, which is fairly consistent with the HEI-2015 score distribution in the US population (99th percentile 81.2/100, 81.2%) (Reedy et al. 2018). Theoretically, perfect adherence to the CFG-2019 should yield an HEFI-2019 score of 80 points. A relatively low 99th percentile of the HEFI-2019 score suggest that full adherence to all recommendations in CFG-2019 may be challenging. However, those recommendations are not a specific set of targets that a population must achieve every day; they are intended to guide Canadians towards healthier eating patterns in general as well as to help shift the food environment towards healthier options.

Statistical methods such as the NCI methods allow the estimation of usual intake distributions when repeated measurements of dietary intake data measured by 24-hour recalls are available (Zhang et al. 2011). The population ratio method can also be used to estimate mean intakes at the population even when dietary intake data are obtained from only one 24-hour recall (Freedman et al. 2008). These methods are encouraged to calculate "usual" or population mean HEFI-2019 scores. Measuring adherence to dietary guidelines at the individual level, such as in a clinical research setting for example, is something that should be undertaken using more than 1 day's worth of dietary intake data. Indeed, a single individual HEFI-2019 score based on dietary intake data from a single 24-hour recall does not reflect long-term or "usual" adherence to CFG-2019 recommendations and needs to be interpreted with great caution (Kirkpatrick et al. 2018; National Cancer Institute 2020; Thompson et al. 2015). Although informed by and tested with dietary intake data collected using repeated 24-hour recalls to model and estimate usual intakes, the HEFI-2019 can theoretically be used with other data sources that provide information on the total diet, from which food, beverage and nutrient intakes can be estimated. To that extent, further research is needed to explore how the HEFI-2019 performs using dietary intake data derived from food records or food-frequency questionnaires.

The present study has several strengths including the use of population data consistent with the target population for the index, the use of multiple metrics to evaluate the psychometric

properties of the HEFI-2019, and a prespecified analysis plan. The HEFI-2019 was developed in close collaboration with Health Canada to ensure full alignment with dietary guidelines. Limitations must also be considered. First, the HEFI-2019 is influenced by the quality of the input dietary intake data, which are prone to random and systematic errors. However, dietary intake data derived from 24-hour recalls are less prone to systematic error than data collected using other instruments such as food-frequency questionnaires or screeners (Freedman et al. 2014, 2015; Thompson et al. 2015). Second, the ability of the HEFI-2019 to be sensitive to changes over time was not assessed due to the cross-sectional nature of the CCHS-Nutrition 2015 and requires further investigation. Third, the validity and reliability of the HEFI-2019 for use among pregnant women, individuals with specific dietary requirements and individuals receiving care in a clinical setting remains to be determined. However, it is stressed that CFG-2019 and the HEFI-2019 are not intended to reflect specific guidance for populations with particular needs. Finally, the extent to which HEFI-2019 scores are associated with health outcomes has not yet been determined.

Conclusion

The objective of this study was to evaluate the psychometric properties of the HEFI-2019, which was developed to reflect adherence to the healthy food choices recommendations in CFG-2019. Overall, analyses revealed adequate properties supporting the use of the HEFI-2019 to assess diet quality relative to federal dietary guidance for Canadians. We suggest that both the total HEFI-2019 and the component scores be examined when using the metric to obtain a more complete assessment of adherence to the different recommendations regarding food choices in CFG-2019.

Competing interests statement

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Contributors' statement

D.B. wrote the first draft of this paper and was responsible for all statistical analyses. All authors have contributed to this work by providing feedback throughout the evaluation of the HEFI-2019 as well as by critically reviewing this paper. B.L. obtained funding from Health Canada for this work and had final responsibility in finalizing this paper. All authors have read and approved the final version of this manuscript.

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Data availability statement

Data pertaining to the 2015 Canadian Community Health Survey-Nutrition (Public Use Microdata Files) are available upon request to Statistics Canada online: https://www150.statcan.gc.ca/n1/en/catalogue/82M0024X2018001.

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Appendix A

Table A1. Details about menu based on randomly selected recipes from Canada's Food Guide 2019.

	Recipe name		
Meal	Menu 1	Menu 2	Menu 3
Breakfast	Eat Your Greens Frittata[a]	Good Morning Egg Roll-Up	Overnight Oats[a]
Lunch	Hearty Chicken Noodle Soup[a]	Toasted Barley and Wild Rice Salad[a]	Lunch box tuna salad wrap
Dinner	Fun Flatbread Pizza	Quinoa and Veggie Casserole	Couscous with Vegetables
Snacks	Fun Fruit Salad	Savoury Pear and Cheese Scones	Fruit Kebabs with Maple Cinnamon Yogurt Dip

Note: Recipes were selected using stratified random sampling among a pool of 69 recipes. The strata of recipes were breakfast, lunch or dinner, and snack. The sample size for each selection was 1–2–1, which represents 1 breakfast, 2 lunch/dinner and 1 snack. The process was repeated independently 3 times to obtain 3 days of menu. Each menu was then standardized to 1800 kcal, which is approximately the median energy intake of individuals aged 19 years and older from CCHS-Nutrition 2015. CCHS, Canadian community Health Survey; HEFI-2019, Healthy Eating Food Index-2019.

[a]Skim milk or water were ingredients included in these recipes. Skim milk was classified under Protein foods as well as Beverages and water was classified under Beverages, according to the HEFI-2019.

Table A2. Estimated means and percentiles of HEFI-2019 component and total scores in Canadians aged 2 years and older.

		Percentile								
Component	Mean (SE)	1	5	10	25	50	75	90	95	99
Vegetables and fruits, /20	9.3 (0.1)	2.5	3.9	4.9	6.6	9.0	11.7	14.3	16.0	19.0
Whole-grain foods, /5	1.2 (0.0)	0.0	0.1	0.3	0.6	1.1	1.6	2.2	2.6	3.5
Grain foods ratio, /5	1.3 (0.0)	0.0	0.2	0.3	0.7	1.3	1.9	2.4	2.7	3.3
Protein foods, /5	4.5 (0.0)	2.4	3.0	3.4	4.1	5.0	5.0	5.0	5.0	5.0
Plant-based protein foods, /5	1.4 (0.0)	0.0	0.1	0.2	0.5	1.2	2.0	3.0	3.5	4.6
Beverages, /10	7.5 (0.0)	2.8	4.2	5.1	6.5	7.8	8.9	9.6	9.8	10.0
Fatty acids ratio, /5	2.2 (0.0)	0.0	0.4	0.7	1.3	2.1	3.0	4.0	4.7	5.0
Saturated fats, /5	3.7 (0.0)	0.0	0.5	1.4	2.7	4.1	5.0	5.0	5.0	5.0
Free sugars, /10	7.0 (0.1)	0.0	0.0	0.6	4.6	8.4	10.0	10.0	10.0	10.0
Sodium, /10	5.0 (0.1)	0.0	0.9	2.0	3.6	5.2	6.5	7.7	8.3	9.5
Total score, /80	43.1 (0.2)	22.1	27.6	30.9	36.7	43.4	49.7	55.0	57.9	62.9

Note: The HEFI-2019 was calculated based on usual dietary intakes modelled using the National Cancer Institute's multivariate method (see Methods section). CCHS, Canadian Community Health Survey; HEFI-2019, Healthy Eating Food Index-2019. Adapted from Statistics Canada, Canadian Community Health Survey-Nutrition: Public Use Microdata File, 2015, December 2020. This does not constitute an endorsement by Statistics Canada of this product.

Table A3. Estimated means and percentiles of HEFI-2019 component and total scores in Canadians aged 2 years and older, by subgroups.

		Percentile								
Stratum	Mean (SE)	1	5	10	25	50	75	90	95	99
Vegetables and fruits, /20										
Male and female, 2–18 y	8.3 (0.1)	2.7	3.9	4.7	6.2	8.1	10.2	12.4	13.7	16.4
Male, 19 y +	8.9 (0.2)	2.1	3.4	4.3	6.1	8.5	11.3	14.1	15.9	19.3
Female, 19 y +	10.5 (0.2)	3.1	4.8	5.8	7.8	10.3	13.0	15.5	17.0	19.7
Whole-grain foods, /5										
Male and female, 2–18 y	1.3 (0.0)	0.1	0.3	0.5	0.8	1.2	1.7	2.2	2.5	3.2
Male, 19 y +	1.1 (0.0)	0.0	0.0	0.1	0.4	0.9	1.7	2.4	2.9	4.0
Female, 19 y +	1.1 (0.0)	0.1	0.3	0.4	0.7	1.1	1.5	2.0	2.3	2.9
Grain foods ratio, /5										
Male and female, 2–18 y	1.3 (0.0)	0.1	0.3	0.5	0.8	1.2	1.7	2.1	2.4	2.9
Male, 19 y +	1.3 (0.1)	0.0	0.0	0.1	0.5	1.2	2.0	2.6	2.9	3.5
Female, 19 y +	1.4 (0.1)	0.1	0.4	0.5	0.9	1.4	1.9	2.4	2.7	3.2
Protein foods, /5										
Male and female, 2–18 y	4.6 (0.0)	2.5	3.2	3.6	4.3	5.0	5.0	5.0	5.0	5.0
Male, 19 y +	4.5 (0.0)	2.3	3.0	3.4	4.1	5.0	5.0	5.0	5.0	5.0
Female, 19 y +	4.4 (0.0)	2.3	3.0	3.3	4.0	4.8	5.0	5.0	5.0	5.0
Plant-based protein foods, /5										
Male and female, 2–18 y	1.0 (0.1)	0.0	0.1	0.2	0.4	0.8	1.5	2.2	2.7	3.6
Male, 19 y +	1.5 (0.1)	0.0	0.1	0.3	0.6	1.3	2.1	3.0	3.6	4.6
Female, 19 y +	1.6 (0.1)	0.0	0.1	0.2	0.6	1.4	2.4	3.3	3.9	5.0
Beverages, /10										
Male and female, 2–18 y	7.2 (0.1)	2.7	4.0	4.8	6.1	7.5	8.6	9.4	9.7	9.9
Male, 19 y +	7.2 (0.1)	2.3	3.7	4.5	5.9	7.4	8.7	9.5	9.8	10.0
Female, 19 y +	8.1 (0.0)	3.9	5.4	6.1	7.3	8.4	9.2	9.7	9.8	10.0
Fatty acids ratio, /5										
Male and female, 2–18 y	1.6 (0.1)	0.0	0.1	0.4	0.9	1.5	2.2	2.9	3.4	4.3
Male, 19 y +	2.6 (0.1)	0.2	0.7	1.1	1.7	2.5	3.4	4.5	5.0	5.0
Female, 19 y +	2.4 (0.1)	0.0	0.5	0.8	1.5	2.3	3.2	4.3	4.9	5.0
Saturated fats, /5										
Male and female, 2–18 y	3.4 (0.1)	0.0	0.3	1.2	2.5	3.8	4.9	5.0	5.0	5.0
Male, 19 y +	3.8 (0.1)	0.0	0.6	1.5	3.0	4.4	5.0	5.0	5.0	5.0
Female, 19 y +	3.7 (0.1)	0.0	0.5	1.4	2.8	4.2	5.0	5.0	5.0	5.0
Free sugars, /10										
Male and female, 2–18 y	5.3 (0.1)	0.0	0.0	0.0	1.8	5.7	9.0	10.0	10.0	10.0
Male, 19 y +	7.7 (0.1)	0.0	0.0	2.3	6.0	9.5	10.0	10.0	10.0	10.0
Female, 19 y +	7.7 (0.1)	0.0	0.3	2.7	6.1	9.4	10.0	10.0	10.0	10.0
Sodium, /10										
Male and female, 2–18 y	5.3 (0.1)	0.3	2.0	2.8	4.1	5.5	6.7	7.7	8.3	9.4
Male, 19 y +	4.7 (0.1)	0.0	0.5	1.6	3.2	4.9	6.3	7.5	8.2	9.3
Female, 19 y +	4.9 (0.1)	0.0	0.6	1.7	3.4	5.1	6.6	7.8	8.5	9.6
Total score, /80										
Male and female, 2–18 y	39.5 (0.3)	21.3	26.0	28.7	33.7	39.6	45.3	50.1	52.7	57.3
Male, 19 y +	43.3 (0.4)	22.4	28.4	31.7	37.4	43.6	49.5	54.6	57.5	62.4
Female, 19 y +	46.0 (0.4)	22.8	29.3	33.2	39.9	46.7	52.7	57.5	60.1	64.4

Note: The HEFI-2019 was calculated based on usual dietary intakes modelled using the National Cancer Institute's multivariate method (see Methods). HEFI-2019, Healthy Eating Food Index-2019. Adapted from Statistics Canada, Canadian Community Health Survey-Nutrition: Public Use Microdata File, 2015, December 2020. This does not constitute an endorsement by Statistics Canada of this product.

Table A4. Estimated means and percentiles of total HEFI-2019 scores in Canadians aged 2 years and older, by Dietary Reference Intake groups.

		Percentile								
Dietary Reference Intake group	Mean (SE)	1	5	10	25	50	75	90	95	99
2 to 3 y	42.7 (0.6)	24.1	29.0	31.9	37.1	43.0	48.4	52.9	55.6	60.0
4 to 8 y	39.5 (0.5)	21.5	26.0	28.8	33.7	39.5	45.3	50.1	52.7	57.3
Male, 9 to 13 y	37.6 (0.5)	20.2	24.6	27.2	32.0	37.6	43.3	47.9	50.5	55.0
Female, 9 to 13 y	38.7 (0.5)	20.6	25.2	27.9	32.9	38.8	44.5	49.3	51.9	56.4
Male, 14 to 18 y	38.9 (0.6)	21.3	25.9	28.6	33.4	39.1	44.5	49.0	51.5	55.8
Female, 14 to 18 y	40.0 (0.6)	21.7	26.5	29.3	34.4	40.2	45.8	50.4	53.0	57.4
Male, 19 to 30 y	39.6 (0.8)	20.0	25.4	28.5	33.8	39.8	45.4	50.4	53.3	58.5
Female, 19 to 30 y	42.2 (0.8)	20.3	26.1	29.4	35.8	42.8	49.0	54.0	56.7	61.4
Male, 31 to 50 y	44.0 (0.6)	23.4	29.4	32.6	38.2	44.2	50.0	54.9	57.6	62.5
Female, 31 to 50 y	46.2 (0.6)	23.6	30.2	34.1	40.5	46.9	52.6	57.2	59.7	64.0
Male, 51 to 70 y	44.5 (0.5)	23.6	29.8	33.1	38.8	44.8	50.6	55.5	58.2	63.0
Female, 51 to 70 y	47.9 (0.5)	24.8	31.5	35.5	42.1	48.6	54.4	59.0	61.4	65.6
Male, 71 y or older	43.8 (0.6)	22.1	28.1	31.6	37.5	44.1	50.3	55.5	58.5	63.3
Female, 71 y or older	45.1 (0.6)	21.9	28.2	32.1	38.7	45.8	52.0	57.0	59.7	64.0

Note: The HEFI-2019 was calculated based on usual dietary intakes modelled using the National Cancer Institute's multivariate method (see Methods). HEFI-2019, Healthy Eating Food Index-2019. Adapted from Statistics Canada, Canadian Community Health Survey-Nutrition: Public Use Microdata File, 2015, December 2020. This does not constitute an endorsement by Statistics Canada of this product.

Fig. A1. Estimated cumulative distribution of the HEFI-2019 component scores in Canadians aged 2 years and older from the 2015 CCHS-Nutrition, based on usual intakes. Usual intakes were estimated using the National Cancer Institute's multivariate method (see Methods section). CCHS, Canadian Community Health Survey; HEFI-2019, Healthy Eating Food Index-2019.

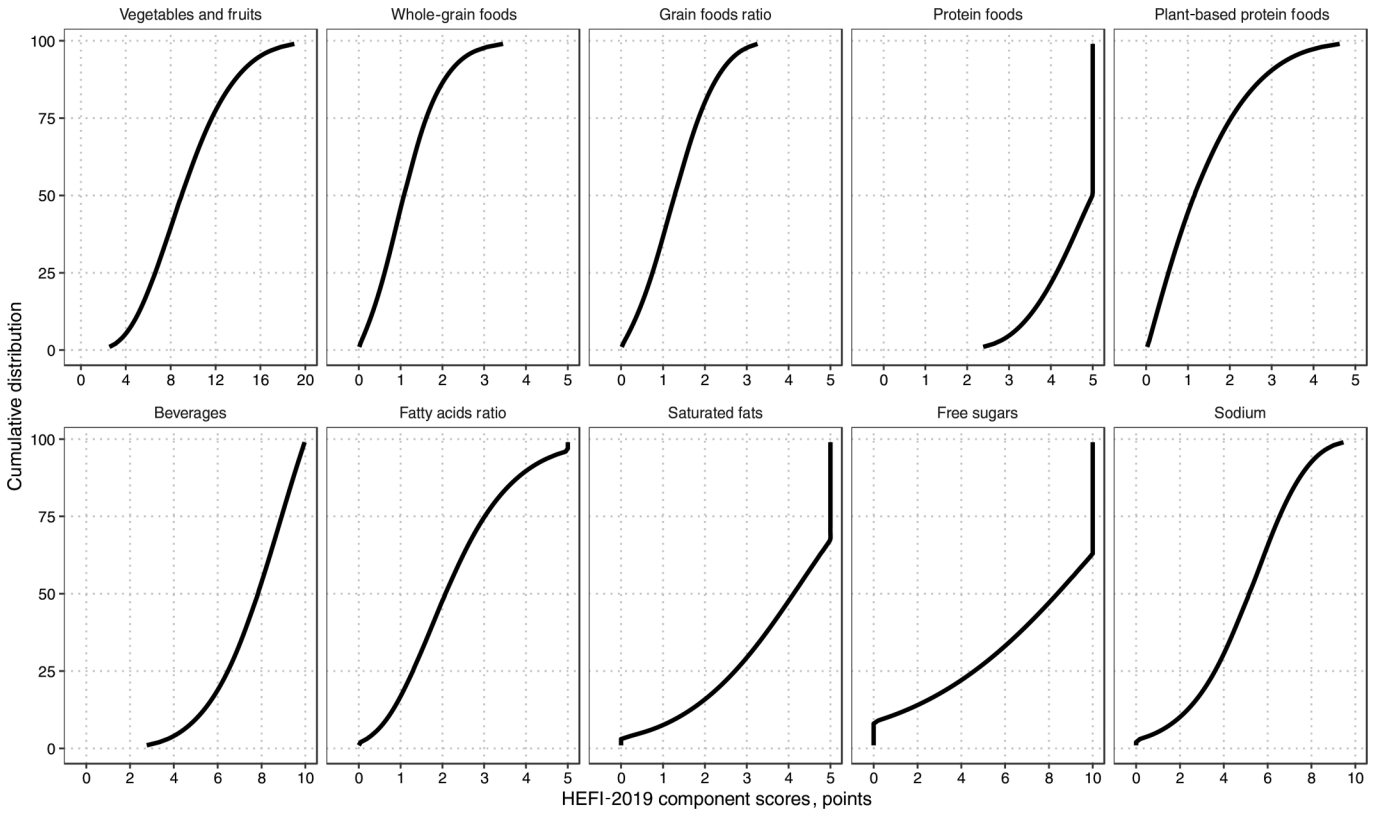

Fig. A2. Scree plot resulting from applying principal component analysis in Canadians aged 2 years and older from the 2015 CCHS-Nutrition on all components of the HEFI-2019, based on usual intakes. Usual intakes were estimated using the National Cancer Institute's multivariate method (see Methods section). CCHS, Canadian Community Health Survey; HEFI-2019, Healthy Eating Food Index-2019.

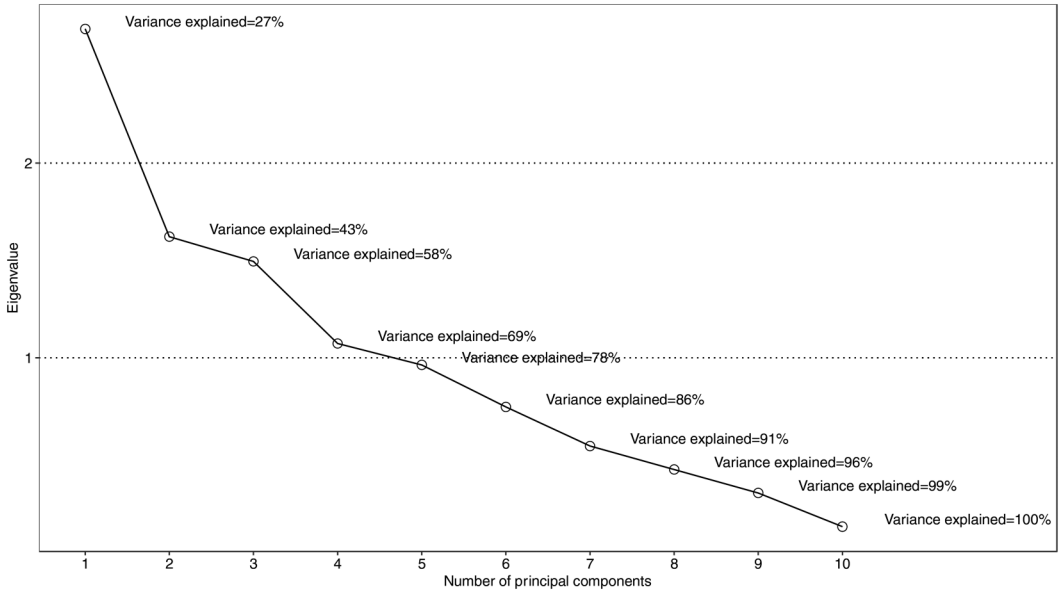

Fig. A3. Eigenvector weights associated with the 4 main principal components identified in the principal component analysis in Canadians aged 2 years and older from the 2015 CCHS-Nutrition, based on usual intakes. Usual intakes were estimated using the National Cancer Institute's multivariate method (see Methods section). A greater eigenvector weight indicates that the HEFI-2019 score component contributes to a greater extent to a given principal component vector. Within a given principal component vector, the HEFI-2019 score components are sorted by eigenvector weight value to reflect their greatest contribution to that given vector. CCHS, Canadian Community Health Survey; HEFI-2019, Healthy Eating Food Index-2019.