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Relative validity of a web-based, self-administered, 24-h dietary recall to evaluate adherence to Canadian dietary guidelines

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ABSTRACT

Objectives: A new, web-based, 24-h recall (R24 W) was developed and programmed to assess adherence to Canadian dietary guidelines by automatically generating the Canadian Healthy Eating Index 2007 (C-HEI 2007). The aim of the present study was to determine the relative validity of the R24 W in terms of its ability to generate C-HEI 2007 scores that match those derived from a food record (FR).

Methods: A total of 57 women and 50 men filled a 3-d FR and three 24-h food recalls with the R24 W. C-HEI 2007 was calculated with both dietary assessment tools and compared using de-attenuated correlations and kappa scores. Internal validity (correlations between total score and components) and external validity (comparison of the C-HEI 2007 by sex and age groups) were compared between the two dietary assessment methods.

Results: The average C-HEI 2007 score obtained with the R24 W (59.4 ± 11.8) was significantly lower than the one obtained with the FR (62.6 ± 11.1). However, the de-attenuated correlation coefficient between C-HEI 2007 obtained either with R24 W or FR was 0.80 ($P < 0.01$) and 91.6% of participants were classified in the same or adjacent quartile of C-HEI 2007 with both tools. Women obtained a higher C-HEI 2007 mean score ($P < 0.01$) with both methods and older adults (age: >51 y) received a higher score than younger adults (age: 18–30 y; $P < 0.01$) with the R24 W but not with the FR ($P = 0.22$).

Conclusions: Although the R24 W yields lower C-HEI 2007 scores compared with data from FR, the classification of individuals was highly consistent between the two measurements.

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Introduction

In Canada, dietary guidelines are issued by Health Canada. The latest revision was proposed in 2007 in Canada's Food Guide (CFG) [1]. The food patterns proposed in the CFG were first developed to achieve age- and sex-specific targets. These recommendations are based on evidence of the relationship between food intakes and chronic diseases [2]. Next, the food patterns developed were analyzed and required to yield <10% of diets that did not reach the Estimated Average Requirement from the Institute of Medicine [3] or the Adequate Intake for nutrients that did not have an Estimated Average Requirement. A subsequent analysis by Elvidge Munene et al. [4] demonstrated that diets that are in line with CFG achieve this last objective.

A recent meta-analysis demonstrated that appropriate intakes of whole grains, vegetables, fruit, nuts, and fish lead to a considerable reduction in preventable deaths [5]. These food items are all promoted by CFG. This is one of the key reasons why an assessment of adherence to dietary guidelines is critical. However, few validated tools have been developed to measure this. The Healthy Eating Index (HEI) was first proposed by Kennedy et al. in 1995 to assess adherence to the United States Department of Agriculture nutritional guidelines [6]. Updated versions were published with revisions of the guidelines in 2005 [7], 2010 [8], and 2015 [9]. Some Canadian adaptations of the initial American HEI-1995 have been proposed since 2000 [10–12]. The Canadian Healthy Eating Index 2007 (C-HEI 2007), which is an updated version inspired by the American HEI-2005, was proposed and validated by Garriguet in 2009 [13]. This tool was developed to measure adherence to the 2007 CFG, which is the latest version of the Canadian guidelines.

The validation of new dietary assessment tools is imperative in order to get an adequate representation of dietary intakes. Different types of validation strategies exist and the strategy choice depends on the aspects of the tool that needs to be validated [14]. For example, the use of biomarkers is relevant when focusing on specific nutrients in the validation strategy. However, this is not the most appropriate approach when aiming to validate the ability of a tool to describe overall diet quality. In such a context, a relative validity assessment is a more appropriate approach. Relative validity refers to the comparison between food intakes that are assessed with the new method and those assessed with a reference method [14]. The food record (FR) is often selected as a comparator because of its production of minimal memory biases and its unstructured form, which reduces any systematic bias [15].

We recently developed a self-administered web-based 24-h recall (R24 W) that is intended to assess adherence to the Canadian dietary guidelines by automatically generating a C-HEI 2007 score [16]. Its validity was evaluated first in the context of fully controlled feeding studies [17]. The aim of this study was to test the relative validity of the R24 W in terms of its ability to generate C-HEI 2007 scores that match those obtained with a reference method (i.e., FR).

Methods

Participants

A total of 75 women and 75 men with ages between 18 and 68 y from the Quebec City area volunteered to take part in the validation study of the R24 W. To be included in the study, participants had to be free from gastrointestinal disorders to avoid interference with blood biomarkers, which were collected for future analyses, and women could not be pregnant or lactating. Two men failed to complete all four dietary recalls and were excluded from the analysis. The protocol was in accordance with the declaration of Helsinki and certified by the Laval University Ethics Committee. All subjects signed a consent form before enrolling in the study.

Anthropometric and food intakes assessment

Weight, height, and waist circumference were measured by research assistants during a visit to the study laboratory using standardized methods [18]. The scale (body composition analyzer BC-418; Tanita Corporation of America, Inc., Arlington Heights, IL) had a capacity of 200 kg and the minimum graduation was 100 g. Height was measured without shoes using a height rod stadiometer (Model 216, SECA, SECA Corp, Hamburg, Germany) at the nearest 0.1 cm. The waist circumference measurement was taken at the end of a normal expiration with a tape placed horizontally directly on the skin at the mid-distance between the last rib and the top of the iliac crest. Waist circumference was determined as the mean of three measurements at the nearest 0.1 cm.

Subsequently, participants received detailed instructions by trained staff on how to fill a 3-d, paper-based FR. Participants could decide which days they wanted to report on as long as they included one weekend day. Participants were encouraged to weigh all the items and report brand names or recipes when possible to improve the precision and accuracy of the record. Every FR was revised by a trained dietitian upon its submission to ensure that the information was complete, accurate, and clear to minimize any possible bias, as the FR was to be used as the reference method in this validation study.

During the following 3-wk period, participants received, on four unannounced days, a web link by e-mail to fill a 24-h recall using the R24 W. A detailed description of the development process of R24 W was published elsewhere [16]. To standardize the methodology for this study, three out of the four collected days were used, and only participants who completed at least one weekend day and two weekdays were included in the analysis (107 participants). For all participants, the first 3 d that included one weekend day were used in the analysis.

Canadian Healthy Eating Index 2007 score

The scoring system is detailed in Table 1. The same codification technique was used to assess the C-HEI 2007 with the R24 W and FR. The calculation was programed to be automatically obtained with the R24 W. For the FR, trained staff manually coded all entries. First, complex meals were decomposed into their main components. Then, all food items and main components of complex dishes were individually scored to determine the number of CFG servings from each of the 11 C-HEI 2007 subscores [1]. Foods with a very high fat content (e.g., fat, dressing, mayonnaise, cream), foods with very high sugar content (e.g., sugar, honey, jam, syrup, sweets, sweetened beverage), foods high in fat, sugar, or salt (i.e., classified in the tier 4 according to the 2014 Health Canada Surveillance Tool Tier System [19]), and other ingredients and beverages (e.g., unsweetened beverage, sauce, condiment) were included in the other foods subscore of the C-HEI 2007 [16]. Lastly, the number of daily servings consumed was used to calculate the C-HEI

Table 1
Description of Canadian Healthy Eating Index 2007 scoring for adults*

Component	Range of scores	Scoring criteria
Adequacy†	0−60 points	
Total vegetables and fruit	0−10 points	Minimum: 0
		Maximum: 7−8 servings
Whole fruit	0−5 points	Minimum: 0
		Maximum: 1.5−1.7 servings (21% of recommended total vegetables and fruits)
Dark green and orange vegetables	0−5 points	Minimum: 0
		Maximum: 1.5−1.7 servings (21% of recommended total vegetables and fruits)
Total grain products	0−5 points	Minimum: 0
		Maximum: 6−8 servings
Whole grains	0−5 points	Minimum: 0
		Maximum: 3−4 servings (50% of recommended total grain products)
Milk and alternatives	0−10 points	Minimum: 0
		Maximum: 2−3 servings
Meat and alternatives	0−10 points	Minimum: 0
		Maximum: 2−3 servings (150−225 g)
Unsaturated fats	0−10 points	Minimum: 0
		Maximum: 30−45 g
Moderation‡	0−40 points	
Saturated fats	8−10 points	Minimum 7%−10% of total energy intake
	0−8 points	10% to maximum 15% of total energy intake
Sodium	8−10 points	Adequate intake to tolerable upper intake level
	0−8 points	Tolerable upper intake level to twice tolerable upper intake level
"Other food"	0−20 points	Minimum: ≤5% of total energy intake
		Maximum: ≥40% of total energy intake

* Adapted from Garriguet [13]
† Zero points for minimum, 5 or 10 points for maximum or more, and proportional for amounts between minimum and maximum.
‡ Ten or 20 points for minimum or less, 0 points for maximum or more, and proportional for amounts between minimum and maximum.

Table 2
Characteristics of participants

	All participants (n = 107)	Women (n = 57)	Men (n = 50)
Age (y)	47.4 (13.3)	50.1 (11.1)	45.1 (14.2)*
Weight (kg)	72.6 (17.5)	64.7 (11.3)	81.4 (19.0)*
Body mass index (kg/m^2)	25.5 (4.4)	24.7 (4.1)	25.6 (4.4)
Overweight and obese (%)	47.7	40.4	56.0
Waist circumference (cm)	89.1 (13.4)	83.7 (10.8)	92.3 (13.5)*

Data presented as mean (standard deviation)
* Significantly different from women ($P < 0.05$)

2007 subscore by age and sex. Rather than calculating the average score on the basis of the average number of servings consumed over 3 d, the scores of each day were computed and averaged. This technique was selected to better reflect the day-to-day variation in intakes.

Statistical analyses

The differences between C-HEI 2007 and components that were derived from the R24 W and 3-d FR were assessed with paired *t* test. Then, associations between the C-HEI 2007 that were computed from the R24 W and 3-d FR were tested with the Spearman deattenuated correlations (i.e., adjusted for within-subject variability). Cross-classification and kappa scores were also used to assess concordance in C-HEI 2007 between the two food assessment methods. Associations between the total score and all components were also evaluated for the two food assessment methods with Spearman correlations. Subsequently, to assess the similarities between the C-HEI 2007 as assessed with the R24 W and 3-d FR, analyses of external validity were conducted on both. More precisely, total C-HEI 2007 scores were compared between men and women and between age groups to test the hypothesis that women and older adults score higher [13,20]. The age groups selected were the same as those presented by Guenther et al. in the validation process of the American HEI of 2005 and 2010 [21]. The statistical procedures were performed using SAS, version 9.4 (SAS Institute Inc, Cary, NC) and the comparisons of correlation coefficients were computed with MedCalc for Windows, version 15.0 (MedCalc Software, Ostend, Belgium) [22].

Results

Participant characteristics are presented in Table 2. Women were on average older than men ($P = 0.04$) and had a lower body weight ($P < 0.01$) and waist circumference ($P < 0.01$), but body mass index (BMI) did not differ between women and men ($P = 0.18$).

Table 3 presents the comparison between C-HEI 2007 as assessed by FR and R24 W. The average total score assessed with the R24 W was 5.2% lower than the average score obtained with the FR ($P < 0.01$). The association between the two tools was characterized by a deattenuated correlation coefficient of 0.80 ($P < 0.01$) and weighted kappa of 0.49. A total of 91.6% of the participants were classified in the same or adjacent quartile of C-HEI 2007 scores, as determined by the two

methods. The subscore for the components vegetables and fruit, saturated fat, sodium, and other foods were significantly lower when assessed with R24 W compared with the FR. The deattenuated correlation coefficients for the associations between the components as assessed by the R24 W and FR were all significant except for meat and alternatives.

The associations between the total C-HEI 2007 score and its components as assessed by the FR or R24 W are presented in Table 4. All Spearman correlations were significant with the FR. For the R24 W, there was no significant association between C-HEI 2007 and the component milk and alternatives as well as the component meat and alternatives. However, there was no difference between R24 W and FR for the strength of the associations between the total score and their components. No significant association was observed between C-HEI 2007 assessed either by FR or R24 W and the reported energy intake (FR: $r_s = -0.14$; $P = 0.14$ and R24 W: $r_s = -0.13$ $P = 0.19$; data not shown).

Table 5 presents the analysis of the external validity of the C-HEI 2007 as measured by the R24 W and FR. On average, women obtained a higher total score than men ($P < 0.01$) with both food assessment methods. Older adults obtained on average a higher total score than younger adults with the R24 W ($P < 0.01$) but not with the FR ($P = 0.22$).

Discussion

In many contexts, diet quality scores gradually tend to replace specific nutrient intakes in nutritional evaluation [23]. Indeed, they allow investigators to capture interactions between nutrients and food consumption patterns. These scores are useful to evaluate the degree of adherence to dietary guidelines. In the present study, the relative validity of 3 d of 24-h dietary recalls assessed with the new R24 W was investigated in relation to a 3-d, paper-based FR to assess adherence to CFG.

Results from this study suggest that the average C-HEI 2007 produced by the R24 W is lower than the score produced by the FR. However, the new tool demonstrated a high level of agreement with the reference method in the classification of respondents. Indeed, 91.6% of individuals were classified in the same or adjacent quartile by both dietary assessment methods, even if the analysis was conducted on different days. The de-attenuated correlation between both methods was also high ($r_s = 0.80$) and the weighted kappa statistics (0.49) indicated a moderate agreement [24]. For all components, the deattenuated correlation coefficient ranged between 0.42 and 0.67 except for the meat and alternatives subscore. However, of note with both tools, several participants (20% with R24 W and 28% with FR) reported consuming on average more servings of meat and alternatives than recommended in CFG. Considering that a perfect score is obtained when intakes meet or exceed the recommendations (Table 1), all those participants

Table 3
Estimated mean C-HEI 2007 components and total score as assessed by FR and the new R24 W and comparison between tools with percent difference, correlation coefficient, cross-classification, and weighted kappa (N = 107)

	FR (SD)	R24 W (SD)	Percent difference (%)	Deattenuated correlation coefficient	Classification in same or adjacent quartile	Weighted kappa
C-HEI 2007 (of 100)	62.6 (13.8)	59.4 (11.8)	−5.2[†]	0.80[†]	91.6	0.49
Total vegetables and fruit (of 10)	7.9 (2.3)	7.4 (2.2)	−6.7[†]	0.67[†]	88.8	0.46
Whole fruit (of 5)	3.6 (1.6)	3.4 (1.6)	−6.6	0.62[†]	79.4	0.29
Dark green and orange vegetables (of 5)	3.1 (1.6)	3.0 (1.4)	−3.9	0.58[†]	81.3	0.30
Total grains products (of 5)	3.7 (1.2)	3.9 (0.9)	5.1	0.41[†]	72.0	0.20
Whole grains (of 5)	3.0 (1.7)	2.7 (1.5)	−10.9	0.48[†]	75.7	0.22
Milk and alternatives (of 10)	6.7 (2.8)	7.0 (2.4)	5.3	0.57[†]	78.5	0.37
Meat and alternatives (of 10)	8.1 (1.9)	8.0 (1.9)	−1.3	0.09	63.5	0.04
Unsaturated fats (of 10)	5.1 (2.9)	5.6 (2.6)	9.8	0.42[†]	73.8	0.20
Saturated fats (of 10)	5.9 (2.9)	5.1 (2.7)	−13.5[†]	0.62[†]	81.3	0.29
Sodium (of 10)	5.4 (2.7)	4.6 (2.5)	−15.0[†]	0.65[†]	83.2	0.40
Other foods (of 20)	10.0 (5.8)	8.8 (4.6)	−13.4*	0.49[†]	78.5	0.25

C-HEI 2007, Canadian Healthy Eating Index 2007; FR, food record; R24 W, web-based 24-h recall; SD, standard deviation
Data presented as mean (SD)
* $P < 0.05$
† $P < 0.01$

Table 4
Associations between total C-HEI 2007 score and each of its components by food assessment tool (FR and new R24 W; N = 107)

Components	C-HEI 2007 total score assessed by the FR	C-HEI 2007 total score assessed by the R24 W	*P*-value for the comparison in correlation strength
Total vegetables and fruit	0.51[†]	0.61[†]	0.29
Whole fruit	0.57[†]	0.58[†]	0.91
Dark green and orange vegetables	0.45[†]	0.55[†]	0.33
Total grain products	0.21[*]	0.20[*]	0.94
Whole grains	0.54[†]	0.53[†]	0.92
Milk and alternatives	0.27[†]	0.14	0.32
Meat and alternatives	0.33[†]	0.13	0.13
Unsaturated fats	0.30[†]	0.42[†]	0.32
Saturated fats	0.57[†]	0.50[†]	0.48
Sodium	0.34[†]	0.29[†]	0.69
Other foods	0.79[†]	0.76[†]	0.58

C-HEI 2007, Canadian Healthy Eating Index 2007; FR, food record; R24 W, web-based 24-h recall
[*] *P* < 0.05
[†] *P* < 0.01

received 10 out of 10 for this component. This produced a plateau effect that can explain a very low correlation (r_s = 0.09).

C-HEI 2007 as assessed by the R24 W was significantly lower than that assessed by the FR (−5.2%). The subscore for saturated fatty acids (−13.5%), sodium (−15.0%), and other foods (−13.4%) were all lower when assessed with the R24 W, which indicates a greater consumption of these nutrients or food items when assessed with the R24 W. Meanwhile, the subscore for the vegetables and fruit component was also lower (−6.7%) and in this case showed a lower consumption when assessed with the R24 W. These differences between the R24 W and FR could be attributed to the inherent differences of the two methods. Even if the FR is often used as a reference method, a certain level of reactivity bias is induced with respondents. Indeed, awareness that food intakes are being evaluated could cause participants to change their usual habits to appear more in line with some social standard or to simplify their meals and save time while reporting them [25].

With an unannounced, retrospective, 24-h dietary recall, respondents cannot change their feeding habits. The introduction of web-based and technology-assisted dietary assessment methods such as the R24 W also reduces desirability bias that is often reported in studies with administered questionnaires because of the perceived anonymity with which they are associated [26,27]. However, 24-h dietary recalls are not free from bias. Respondents with less effective short-term memory may be at risk of forgetting some food items they ate the day before. Consequently, the results of the present study could suggest that respondents forgot some of the vegetables and fruits that were consumed when completing the 24-h food recalls. However, they appear less likely to forget sources of saturated fatty acids, sodium, and items of the other foods because their reported intakes were higher with the R24 W

than the FR. These contradictory observations somehow invalidate the hypothesis that a significant memory bias with the R24 W could explain the results obtained.

Lastly, we believe that the lower average diet quality score obtained with the R24 W is an interesting result that suggests that the web-based 24-h recall reduces the propensity to prettify food intakes, which is a recurring criticism of self-reported dietary assessment methods [28].

The patterns of correlations between the total C-HEI score and individual components of the score were similar for both tools. Indeed, we observed that in both cases, other foods, total vegetables and fruit, and whole fruit demonstrated the strongest associations with the total C-HEI score. This supports the observations from Garriguet who showed similar patterns of correlations between individual components and the total score in a cohort representative of the Canadian population [13].

Furthermore, the strength of the associations between each component and the total score did not differ by food assessment method. C-HEI 2007 as assessed with the R24 W did not correlate with the component milk and alternatives and meat and alternatives. In the validation of the American HEI-2010, Gunther et al. [21] also observed that the milk and alternatives (dairy) component did not correlate with the total score, and Garriguet [13] noted the same observation when validating the C-HEI 2007.

As reported by others [13,20,21], we observed that women obtained higher overall scores as determined by the R24 W and FR. However, participants ages ≥51 y obtained a higher C-HEI 2007 score compared with the youngest ones (18−30 y) only with the R24 W. Differences in diet quality between the age groups have been reported by Hiza et al. [29]. The researchers suggested that older adults tend to become more health conscious as they age and try to improve their dietary quality to prevent or manage chronic diseases. As previously explained, FR is more susceptible to reactivity [30] and social desirability bias [31,32], which could result in an overall improvement of the observed diet quality and attenuation of the age-related difference. Our study was not designed to specifically address the contribution of this bias, and further studies are needed to shed light on these issues.

It is important to remember that dietary intakes were captured on different days with the R24 W and FR; therefore, a perfect agreement was not expected. Even if longer observations would have been needed to assess specific nutrients [33], we propose that this time frame was long enough to be representative of usual diet quality [34]. Furthermore, having 3 d during which food intakes were reported could be considered a strength of this study, as most studies on dietary quality scores are conducted on data from food frequency questionnaires and with only 1 d or 2 d of 24-h recalls [12,21]. Having data on food intakes over a longer period of time improves the accuracy of dietary intakes [35,36]. Of note, the validation of the R24 W has been conducted in a cohort of French-Canadian adults; thus, a culturally adapted version may be needed for other populations.

Table 5
Estimated mean C-HEI 2007 score by sex and age group as assessed with the new R24 W and the FR (N = 107)

	Men (n = 50)	Women (n = 57)	Aged 18−30 y (n = 13)	Aged 30−50 y (n = 38)	Aged ≥51 y (n = 56)
R24 W (of 100)	55.7 (11.6)	62.6 (11.1)[*]	51.5 (9.4)	58.5 (12.4)	61.8 (11.2)[†]
FR (of 100)	57.8 (13.3)	66.9 (13.0)[*]	57.6 (13.4)	62.3 (14.0)	64.0 (13.9)

C-HEI 2007, Canadian Healthy Eating Index 2007; FR, food record; R24 W, web-based 24-h recall
Data presented as mean (standard deviation)
[*] *P* < 0.05 compared with men
[†] *P* < 0.05 compared with participants aged 18−30 y

Conclusions

The results from this study suggest that the C-HEI 2007 as assessed by the R24 W demonstrates a good level of agreement with the reference method (i.e., FR). This new web-based method is appropriate to classify respondents by level of adherence to the Canadian nutritional guidelines, as demonstrated by the agreement between the scores that were obtained on different days with a different method. Moreover, the R24 W has the ability to detect expected differences in diet quality between subgroups on the basis of sex and age.

Acknowledgments

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