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RESEARCH PAPER

Validation of a quantitative food frequency questionnaire for Inuit population in Nunavut, Canada

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Abstract

Background: Validation of a quantitative food frequency questionnaire (QFFQ) developed specifically for Inuit is necessary to determine its usefulness in assessing dietary intake and adequacy and in identifying dietary risk factors for chronic disease in this population.
Methods: Seventy-five randomly selected Inuit adults in Nunavut, Canada, were recruited. Mean daily intake of nutrients from one to three 24-h recalls was used as the reference to measure QFFQ validity. Crude and energy-adjusted Spearman rank correlations (ρ), cross classification and weighted kappa were computed as measures of concordance. Bland–Altman plotting was used for additional assessment.
Results: Excluding four participants with daily energy intake of >25.1 MJ, 71 participants were included in the analysis. For all nutrients, mean daily intake from the QFFQ was higher than the recall. ρ's for macronutrients were in the range 0.71 for carbohydrate to 0.25 for protein. The best ρ amongst micronutrients was observed for vitamin C (0.66). Overall correlation between the two dietary tools improved after correction for within-person variance (from 0.46 to 0.49), although adjusting for energy did not improve the overall coefficient. When nutrient intakes were categorised into quartiles, the QFFQ and 24-h recalls indicated relative agreement proportion (same or adjacent quartiles) of 83% for energy, 94% for total sugar, 83% for macronutrients and 77% for micronutrients. Bland–Altman plots showed a tendency for increased scatter of the differences in nutrients at higher intakes.
Conclusions: The QFFQ developed is valid and can be used to assess usual dietary intake and dietary adequacy, determine the contribution of foods to specific nutrient intakes, and identify dietary risk factors for chronic disease amongst this population.

Introduction

Food frequency questionnaires (FFQs) are widely used in epidemiological studies to assess dietary intake and to explore diet and chronic disease associations in specific populations. This instrument is advantageous because it is relatively easy and inexpensive to administer, and can measure dietary intake over a long time period. (Cade *et al.*, 2002). It is critical that a FFQ is culturally appropriate for the population being studied (Teufel, 1997), and it is equally essential to validate newly-developed instruments to ensure that they measure what is intended. FFQs can be validated by comparing responses from the FFQ with those from a reference instrument, such as multiple 24-h recalls (Kroke *et al.*, 1999).

Many validation studies reported a strong correlation between energy and nutrient estimation by a FFQ and a reference method, and a generally accepted amount of misclassification when subjects were cross-classified into quartiles of the distribution of each nutrient under investigation (Goldbohm *et al.*, 1994; Fidanza *et al.*, 1995; Gnardellis *et al.*, 1995; MacIntyre *et al.*, 2001). Although

it is not always applicable, the underlying assumption of this validation approach requires that the measurement error of the test method be independent of the measurement error of the reference method (Willett, 1998). For example, 24-h recalls are likely to correlate with errors observed with the FFQ, such as recall bias and conceptualisation of portion sizes. However, speed, ease of administration and feasibility for interviewing a large number of subjects in the face of limited resources have made multiple 24-h recalls a popular reference method in FFQ validation studies (Kroke *et al.*, 1999; Nelson, 2003).

The quantitative food frequency questionnaire (QFFQ) under study was developed specifically for an Inuit population in Nunavut, Canada, using an established methodology (Sharma *et al.*, 2010a). The present study aimed to assess the relative validity of the 150-item QFFQ to estimate mean daily intake of energy, macronutrients and some micronutrients of interest, comprising those that were determined to be important for targeting in a nutrition intervention programme in this population, by comparing with repeated 24-h dietary recalls. If valid, this tool will be used to assess usual dietary intake and dietary adequacy, determine the contribution of foods to specific nutrient intakes, and identify dietary risk factors for chronic disease amongst this population.

Materials and methods

The QFFQ was developed based on food and nutrient intake data collected from two communities (communities A and B) in Nunavut, Canada. Development of the QFFQ, methods for the 24-h recall collection, as well as recruitment procedures have been described elsewhere (Sharma *et al.*, 2010a; Sharma, 2010b). The study was approved by the Office of Human Research Ethics at the University of North Carolina at Chapel Hill, the Committee on Human Studies at the University of Hawaii, and the Nunavut Research Institute.

Subjects

For the QFFQ validation, 75 participants from Community B were recruited between July and October 2008 (Sharma, 2010b). The inclusion and exclusion criteria for recruiting participants were the same as those used for developing the QFFQ (were Inuit, ≥19 years, resided in the community >6 months, not pregnant/lactating) (Sharma *et al.*, 2010a). However, in this QFFQ validation study, a new random sampling was performed to find households that were not included in the QFFQ development study. Considering the inclusion and exclusion criteria, the main food shopper in each selected household was invited for interview. Once participants were enrolled and consent obtained, QFFQ and up to three 24-h recalls were completed. The methods of administration of the QFFQ have also been described elsewhere (Sharma, 2010b). The QFFQ estimated usual food and drink intake over the past 30 days. The 24-h dietary recalls were administered by trained interviewers. Participants completed one recall per day on three nonconsecutive days (two recalls captured weekday consumption and one captured a weekend day). One participant completed two 24-h dietary recalls, and seven participants completed only one 24-h dietary recalls, which were only on weekdays.

Analysis

Computation of mean daily nutrient intake from the QFFQ

The QFFQ used preweighted food models, household utensils and, for food items without measured portion weights, the Canadian Nutrient File database (10th edition) to estimate portion sizes. For each participant, mean daily intake (g) of each food/beverage item was determined by multiplying daily frequency by the portion size (g) using the formula: $dg_{jk} = dfq_{jk} \times np_{jk} \times gm_k$, where dg_{jk} was the daily grams consumed for subject j and food item k, dfq_{jk} was the daily frequency for subject j and food item k, np_{jk} was the number of portions eaten by subject j for food item k, and gm_k was the grams per portion for food item k. A food composition table (FCT) was constructed specifically for the QFFQ using Canadian food composition tables, analyses of locally collected recipes, and the USDA National Nutrient Database for Standard Reference 20 (USDA, 2007). For each of the 150 food/beverage items, a record was created in the FCT that contained the nutrient content per 100 g of edible portion. The data extracted from three datasets, including the FCT, QFFQ (frequency and amount of intake) and food item portion weights, were analysed by the Food Frequency Questionnaire Analysis Programme in STATA (StataCorp LP, College Station, TX, USA), programmed by the first author, to compute the total daily nutrient intake.

Computation of mean daily nutrient intake from the 24-h recalls

Up to three 24-h recalls were collected from each participant on two weekdays and one weekend day when possible. Food models and portion weights were used to quantify the amount of food consumed. All 24-h recall data were coded, entered and analysed using NUTRIBASE CLINICAL NUTRITION MANAGER, version 7.17 (CyberSoft Inc., Phoenix, AZ, USA). The food composition tables in NUTRIBASE were updated to include 17 weighed recipes that were previously collected for nine different dishes in the study communities. NUTRIBASE software was used to

calculate the nutrient intake for each individual 24-h recall per person based on the Canadian food composition table. An estimate of individual j's daily intake of nutrient k (Y_{jk}), as given by 24-h recalls in weekdays one and two and weekend day three, was computed using the formula:

$$Y_{jk} = \left[\frac{5}{2}\left(Y_{j1k} + Y_{j2k}\right) + 2Y_{j3k}\right] \div 7$$

For those participants with only one or two days of recall collected, the mean intakes were computed.

Statistical analysis

The mean and standard deviation (SD) of each nutrient was computed for both the QFFQ and the 24-h recalls. Spearman's rank correlation was used to measure the strength of the relationship between nutrient intakes estimated by the QFFQ and the reference tool. Spearman correlation coefficients (ρ) were adjusted for within-person daily variability (de-attenuated correlation coefficient) by multiplying an adjustment factor as recommended by Willett (1998). The adjustment factor was computed from the two or three 24-h recalls using the formula: $[1 + ((\sigma_W^2/\sigma_B^2)/m)]^{1/2}$, where m is the mean number of days covered by the recalls, and the within-person (σ_W^2) and between-person (σ_B^2) variances were computed from the days of recall by variance component techniques.

To evaluate the agreement of classification based on the nutrient intakes between the 24-h recalls and the QFFQ, quartile classifications obtained by both methods were compared. The quartiles were created using the instrument specific distribution. The percentages of values that appeared in the same and opposite quartiles were evaluated as measures of agreement and disagreement, respectively. The weighted kappa was computed to provide a chance-corrected measure of cross-classification (Fleiss, 2003) in which the observed and expected proportions of agreement are modified to include partial agreement, by assigning a weight between zero (complete disagreement) and one (complete agreement) to each category (Kirkwood & Sterne, 2003). $P < 0.05$ (two-sided) was considered statistically significant.

The analysis of correlation between the QFFQ and 24-h recall was also performed based on the energy-adjusted values of nutrient intakes and for two age groups of ≤50 and >50 years. The cut-off point of 50 years was chosen to assure that analyses were comparable with the Dietary Reference Intakes. The energy-adjusted values were computed as the residuals from the regression model to be employed as a measure of nutrient intake that is independent of total energy intake (Willett, 1998).

Bland–Altman plots were used to observe the agreement between the QFFQ and the recalls at the individual level. The measurement error was shown by plotting the

Table 1 Correlations between daily intake of energy and nutrients assessed by three 24-h recalls and quantitative food frequency questionnaire (QFFQ) amongst 71 Inuit adults in Nunavut, Canada

Nutrients	QFFQ Mean (SD)	Recall Mean (SD)	Spearman correlation		
			Crude	De-attenuated	De-attenuated and energy-adjusted
Energy (MJ)*	12.24 (5.33)	8.43 (3.21)	0.62†	0.65†	–
Carbohydrate (g)	344 (163)	250 (128)	0.71†	0.74†	0.46†
Total fat (g)	91 (44)	68 (32)	0.51†	0.55†	0.30‡
Protein (g)	172 (104)	100 (54)	0.25‡	0.28‡	0.51†
Dietary fibre (g)	14 (7)	8 (4)	0.45†	0.49†	0.13
Total sugar (g)	168 (100)	126 (84)	0.79†	0.81†	0.56†
Total folate (μg)	314 (137)	194 (100)	0.34†	0.37†	0.40†
Vitamin A (μg RAE)	1404 (2111)	853 (2505)	0.30‡	0.33‡	0.32‡
Riboflavin (mg)	4 (2)	2 (1)	0.55†	0.58†	0.48†
Vitamin B_6 (mg)	2 (1)	1 (0.61)	0.47†	0.51†	0.23
Vitamin B_{12} (μg)	20 (16)	7 (9)	0.41†	0.45†	0.40†
Vitamin C (mg)	201 (145)	170 (196)	0.66†	0.69†	0.24
Vitamin D (IU)	183 (179)	126 (225)	0.33†	0.36†	0.27‡
Vitamin E (IU)	0.73 (0.74)	0.55 (1.25)	0.39†	0.43†	0.14
Calcium (mg)	1104 (582)	722 (585)	0.46†	0.50†	0.37†
Iron (mg)	31 (19)	20 (13)	0.20	0.22	0.37†
Zinc (mg)	22 (15)	12 (8)	0.30‡	0.33‡	0.44†

RAE, retinol activity equivalent.

*1 MJ = 239 kcal.

†$P < 0.01$.

‡$P < 0.05$.

individual differences between the pair of measurements against the mean of each paired measurements (Bland & Altman, 1986). STATA MP, version 10.1 (StataCorp LP, College Station, TX, USA) was used for all statistical analyses.

Results

Of seventy-five Inuit adults that participated in 24-h recalls and the QFFQ (response rate 69%), four participants (5.3%) were excluded as a result of extreme reporting of energy [>25.1 MJ per day (6000 kcal per day)]. In total, 65 women (91.5%) and six men (8.5%) with a mean (SD) age of 44 (17) years and 45 (19) years, respectively, were included in the analysis.

The results of the comparison of the QFFQ and repeated 24-h recalls for the mean (SD) of energy, total sugar, macronutrients and some micronutrients of interest are presented in Table 1. Despite exclusion of over-reporters, mean intakes of all of the nutrients included in the table were greater for the QFFQ than from the 24-h recall mean.

Comparing the QFFQ and repeated 24-h recalls, the Spearman correlation coefficients were in the range 0.20 for iron to 0.79 for total sugar. After correction for within-person variance the correlation coefficient for macronutrients was in the range 0.28 for protein to 0.74 for carbohydrate. Amongst micronutrients under assessment, the weakest and strongest de-attenuated correlation between the two dietary tools was observed for iron ($\rho = 0.22$) and vitamin C ($\rho = 0.69$), respectively.

Cross-classification analyses revealed that 83% of observations for energy, macronutrients, dietary fibre and total sugar, and 77% of observations for micronutrients, placed in the same or adjacent quartiles with a mean weighted kappa of 0.36 and 0.24, respectively (Table 2). Extreme misclassification occurred in 0% of observations for carbohydrate, total sugar and vitamin E, and in 10% of observations for protein and zinc.

Table 3 shows the results of correlation assessment between two dietary assessment instruments for subjects ≤50 years and >50 years, independently. Each of the mean crude, de-attenuated and energy-adjusted correlation coefficients for participants >50 years were smaller than the correspondence correlation coefficients for participants 50 years or younger (0.35, 0.37 and 0.24 versus 0.43, 0.47 and 0.35).

The Bland–Altman plots for energy, total fat, vitamin C and calcium showed heterogeneity (Fig. 1). However, the plotted points were predominantly within the 95% limit of agreement for each nutrient. All plots showed a wide scatter of difference at higher intake, which indicates a closer agreement at lower intake. Plots for energy, total fat and calcium also illustrated a constant pattern of over-estimation of nutrients by the QFFQ compared with the recalls. This pattern was more evident at higher intakes. However, the plot for vitamin C showed a downward pattern, indicating under-estimation of the nutrient by the QFFQ at higher levels of intake. On average, the estimated intakes of energy, total fat, vitamin C and calcium from the QFFQ were higher (45%, 34%, 18% and 53%, respectively) than those from the recalls.

Table 2 Weighted kappa and cross-classification of nutrient distribution quartiles from 24-h recalls and quantitative food frequency questionnaire, amongst Inuit adults ($n = 71$) in Nunavut, Canada; weighted kappa was calculated for each nutrient from the observed and expected proportions on 4 × 4 table of frequency

	Cross-classification (%)			
Nutrients	Same quartile	Adjacent quartile	Opposite quartile	Weighted kappa
Energy (MJ*)	45	38	2	0.41†
Carbohydrate	41	54	0	0.48†
Total fat	38	42	3	0.32†
Protein	30	44	10	0.14
Dietary fibre	39	34	3	0.28†
Total sugar	49	45	0	0.55†
Total folate	39	37	6	0.28†
Vitamin A (RAE)	32	35	7	0.14
Riboflavin	38	48	3	0.37†
Vitamin B_6	33	45	3	0.25†
Vitamin B_{12}	33	49	7	0.25††
Vitamin C	41	49	2	0.44†
Vitamin D	31	41	7	0.16††
Vitamin E	39	35	0	0.15†
Calcium	35	47	7	0.28†
Iron	31	35	7	0.12
Zinc	33	44	10	0.18††

RAE, retinol activity equivalent.
*1 MJ = 239 kcal.
†$P < 0.01$.
††$P < 0.05$.

Discussion

The present study aimed to determine the relative validity of the QFFQ developed for use in tracking dietary changes over time, both in regard to the evaluation of a nutrition intervention programme and continued surveillance. Comparison of means indicated a tendency for higher estimation of nutrient intakes by the QFFQ than the 24-h recalls. However, medium to large correlations (Zou *et al.*, 2003) were observed between the two dietary assessment tools for energy and nine nutrients under study. In addition, more than 70% of observations placed in the same or adjacent quartiles for estimation of nutrient intakes, excluding vitamin A and iron, indicating a good agreement between the QFFQ and the reference tool.

Table 3 Correlations between daily intake of energy and nutrients assessed by three 24-h recalls and quantitative food frequency questionnaire based on age groups amongst Inuit adults (n = 71) in Nunavut, Canada

	Age ≤ 50 years (n = 48)			Age > 50 years (n = 23)		
Nutrients	Crude	De-attenuated	De-attenuated and energy-adjusted	Crude	De-attenuated	De-attenuated and energy-adjusted
Energy	0.54*	0.57*	–	0.26	0.27	–
Carbohydrate	0.66*	0.68*	0.38†	0.29	0.30	0.46†
Total fat	0.47*	0.51*	0.25	0.29	0.31	0.41
Protein	0.28	0.30	0.42*	0.21	0.24	0.35
Dietary fibre	0.39*	0.44*	0.13	0.17	0.18	0.13
Total sugar	0.67*	0.69*	0.53*	0.57*	0.59*	0.16
Total folate	0.52*	0.58*	0.45*	0.02	0.02	0.18
Vitamin A (RAE)	0.19	0.21	0.39†	0.44†	0.48†	0.06
Riboflavin	0.53*	0.57*	0.47*	0.50†	0.54†	0.37
Vitamin B_6	0.36†	0.40†	0.23	0.56*	0.60*	0.15
Vitamin B_{12}	0.40*	0.44*	0.46*	0.51†	0.55†	0.33
Vitamin C	0.53*	0.55*	0.31†	0.69*	0.73*	NC
Vitamin D	0.26	0.28	0.21	0.41	0.45	0.28
Vitamin E	0.35†	0.39†	0.15	0.53*	0.55*	0.22
Calcium	0.47*	0.51*	0.42*	0.28	0.31	0.31
Iron	0.33†	0.36†	0.28	NC	NC	0.42
Zinc	0.38*	0.42*	0.50*	0.18	0.20	NC

RAE, retinol activity equivalents; NC, no correlation.
*$P < 0.01$.
†$P < 0.05$.

Up to three 24-h recalls (covering weekdays and weekend days) were used as the reference dietary assessment tool for evaluation of validity of the QFFQ. No dietary assessment tool provides a perfect measure of dietary intake. However, when choosing a reference tool for a validation study, it is important that the sources of error for the reference tool and the QFFQ are as independent as possible (Nelson, 2003). Major sources of error in the QFFQ include recall bias, misinterpretation of questions and inference of portion sizes provided in the questionnaire. Considering that these types of errors, except recall bias, do not apply to 24-h recalls, and that this dietary assessment tool is feasible for implementation and does not place a substantial burden on subjects (Nelson, 2003), a mean of multiple 24-h recalls is often chosen as a reference scale for QFFQ validation (Cade *et al.*, 2002).

An individual's day-to-day variation in diet (within-person variance) estimated by a limited number of recalls could attenuate correlations between FFQ and 24-h recalls (Willett, 1998). To reduce this effect, the crude correlation coefficients were corrected.

For nutrients with large ratios of within-person to between-person variance, a few days of recall are not sufficient to capture usual intake (Hartman *et al.*, 1990). Although three days of recall may be adequate to measure validity of a QFFQ, it has been reported that correlations between QFFQs and recalls would improve with an increased number of recall days (Mares-Perlman *et al.*, 1993). The highest within-person to between-person variance ratios in the present study were observed for protein and iron. Thus, finding the lowest correlation coefficients for these nutrients is not surprising. Collecting more than three days of recalls was not feasible in this study as a result of participant burden and financial restriction.

Adjustment for energy led to improved agreement between the two instruments for protein, total folate, iron and zinc. However, for the remaining nutrients, the correlation attenuated after adjustment indicating that variability is more related to systematic error of under/over-estimation than to energy intake (Willett, 1998). This could also be a consequence of including a considerable number of food items in the QFFQ with substantial contribution to energy intake. The QFFQ developed for Nunavut includes 23 non-nutrient-dense foods that contributed to approximately 33% of energy consumed. The QFFQ was developed to include both traditional and shop-bought foods because the consumption of these would be monitored over time. It has been demonstrated that QFFQs that include a large number of items from a specific food group are likely to over-estimate intake (Krebs-Smith *et al.*, 1995; Amanatidis *et al.*, 2001). The attenuation of correlation after adjusting for energy has been reported previously (Martin-Moreno *et al.*, 1993; Jackson *et al.*, 2001; Kim *et al.*, 2002; Fornés *et al.*, 2003;

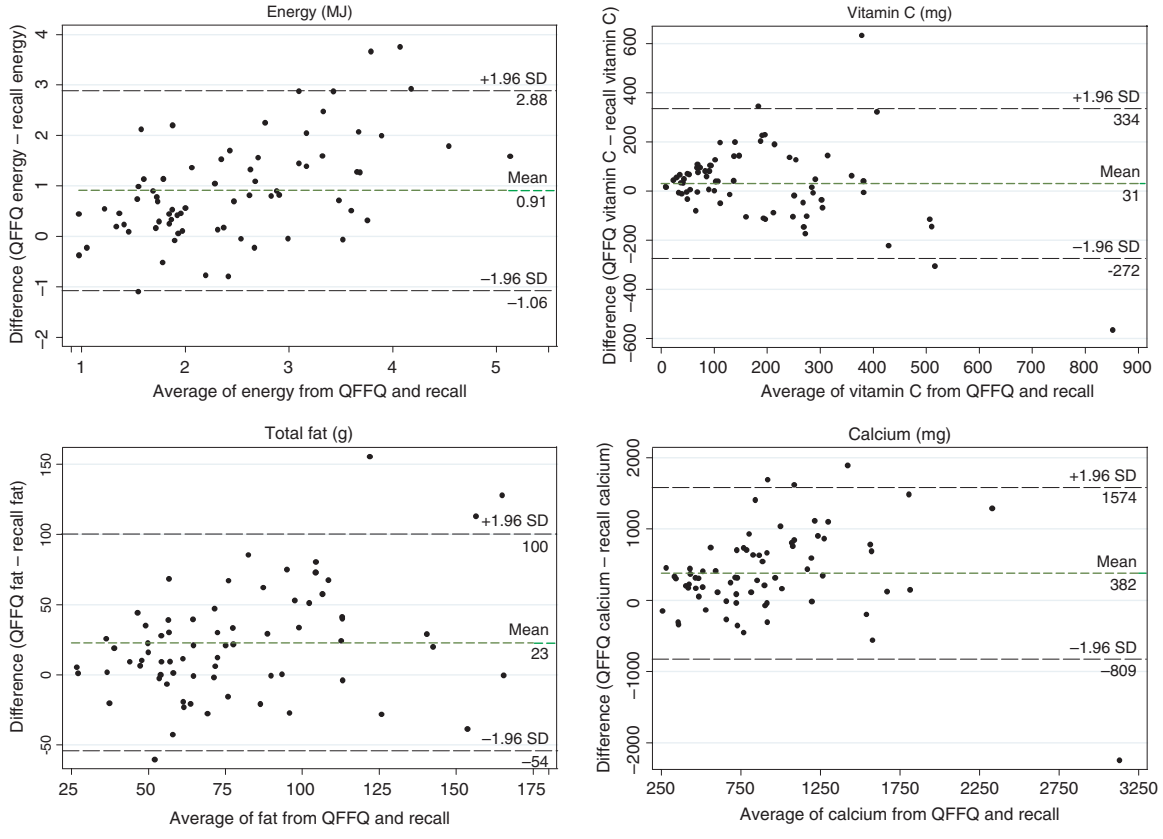

Figure 1 Bland–Altman plots for energy, total fat, vitamin C and calcium. Difference in nutrients intake estimated by quantitative food frequency questionnaire (QFFQ) and 24-h recall plotted against the mean of nutrients intake measured by the two methods for Inuit adults (n = 71) in Nunavut, Canada.

Deschamps *et al.*, 2009). On the other hand, some studies reported higher coefficients after adjustment (Willett *et al.*, 1985; Cardoso *et al.*, 2001; Wengreen *et al.*, 2001).

Unlike correlation analysis, the cross-classification procedure is able to capture differential under- and over-reporting (Friis *et al.*, 1997). In the present study, despite some differences in estimation of nutrients, agreement in terms of classification was good. More than 70% of participants were classified in the same or adjacent quartiles for all of the nutrients, except vitamin A and iron, by both methods and this is similar to other studies (van Liere *et al.*, 1997; Marchioni *et al.*, 2007; Deschamps *et al.*, 2009). Misclassification was higher for protein and zinc.

Utilising the Bland–Altman plots to assess individual validity showed that agreement between the QFFQ and 24-h recalls was inconsistent across the range of intakes for energy, total fat, vitamin C and calcium. Nevertheless, the agreement between the two methods was better for participants who consumed less. This is indicative of possible over- or under-reporting on the QFFQ for those participants who had higher intake.

Measurement of correlation between the QFFQ and 24-h recalls for two age groups revealed a general decrease in correlation for participants older than 50 years. This finding indicates a consistent difference in older respondents' (>50 years) ability to complete questionnaires satisfactorily, possibly as a result of their unfamiliarity with shop-bought foods listed on the QFFQ. The diet of the older participants was mostly traditional, and therefore different from that of the younger age group. A number of factors such as gender, age and socioeconomic factors may be associated with the validity of dietary estimates (Nelson, 2003). However, Marks *et al.* (2006) and Pellegrini *et al.* (2007) did not find any significant effect of age on questionnaire validation. The former study argued that, of all the personal characteristics studied (e.g. age, gender, body mass index, occupation and medical condition), gender was most commonly associated with intake estimate errors for food groups. Because of the small sample size, analysis of correlation for gender groups was not performed in the present study, which introduced a gender bias.

It has been suggested that increasingly long and detailed questionnaires are less likely to obtain accurate

data (Willett, 1998). A literature review by Cade *et al.* (2002) reported a median number of 79 food items (range 5–350) for food frequency questionnaires. Therefore, the 150-item QFFQ used in the present study could be considered an acceptable length. Moreover, it has been designed to be culturally appropriate because it contains local and traditional food/beverage items and utilises appropriate portion sizes. The QFFQ collected data over a 30-day period; thus, seasonal variation is not a major factor in the present study.

In conclusion, the QFFQ is a valid tool to estimate dietary intake in Inuit in Nunavut and can be used to assess dietary intake and contribution of foods to nutrients of interest at pre- and post-intervention. In addition, it can be used to identify dietary risk factors for chronic disease amongst this population and to track changes in diet over time.

Conflict of interests, source of funding and authorship

The authors declare they have no conflicts of interest. The project was supported by American Diabetes Association Clinical Research award 1-08-CR-57, Government of Nunavut Department of Health and Social Services, Health Canada, Public Health Agency of Canada and Northwest Territories and Nunavut Public Health Association. SS developed the conception and design of the study. MP contributed to data analysis, and both authors were responsible for data interpretation. MP and SS drafted the manuscript, critically reviewed its content and have approved the final version submitted for publication.

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