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RESEARCH PAPER

# Validation of a culturally appropriate quantitative food frequency questionnaire for Inuvialuit population in the Northwest Territories, Canada

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## Abstract

**Background:** The estimation of dietary intake in population-based studies is often assessed by a food frequency questionnaire (FFQ). This present study aimed to establish the validity of a 142-item quantitative FFQ (QFFQ) developed to assess dietary intake in a population living in the Northwest Territories, Canada, and undergoing rapid nutrition transition.
**Methods:** Sixty-four randomly selected Inuvialuit adults were recruited. The mean of one to three 24-h recalls was used as the reference to measure the validity of the QFFQ. Spearman rank correlations ($\rho$), cross-classification and weighted kappa were computed as measures of concordance, adjusting for the daily dietary intake variations in the recalls. Bland – Altman plots were used for additional assessment.
**Results:** Four participants with daily energy intake of >25.1 MJ were not included in the analysis. For all nutrients, mean daily intake estimations were higher from the QFFQ than from the recalls. De-attenuated $\rho$'s for macronutrients ranged from 0.33 (protein) to 0.45 (carbohydrate). The best de-attenuated $\rho$ amongst micronutrients was observed for vitamin C (0.53). Overall correlation between the two dietary tools improved after correction for within-person variance (from 0.32 to 0.35). When nutrient intakes were categorised into quartiles, the QFFQ and 24-h recalls indicated relative agreement (same or adjacent quartiles) for 77% for energy and macronutrients, 86% for total sugar and 72% for micronutrients. Bland–Altman plots showed a tendency for increased scatter of the differences 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 Inuvialuit.

## Introduction

The food frequency questionnaire (FFQ) is a dietary assessment instrument with several advantages over other methods. It can capture past dietary intake patterns and also allows for assessment of food intake over an extended period of time (Nelson & Bingham, 2003; Subar, 2004). In addition, it is considerably less expensive to administer with regard to both time and cost compared with other dietary assessment tools, an important consideration in large cohort studies. However, when using FFQs to assess dietary intake in populations with different dietary practices and food uses, it is critical that the instrument is adapted so that it is culturally appropriate (Teufel, 1997). Newly-developed or adapted FFQs must be validated to ensure accuracy in assessing the dietary intake of the population of interest.

 

A widely-used method for FFQ validation is comparison with a reference method such as biomarkers, dietary records and/or multiple 24-h recalls. However, none of these methods are able to measure true intake without limitations. Although arguably more objective than other methods, a biomarker is usually costly, is used to validate the FFQ for only one nutrient and is considered an invasive method compared with dietary records or recalls (Nelson, 2003). Dietary record has been suggested as the first method of choice for FFQ validation (Cade *et al.*, 2002) because its estimation error is usually not correlated with errors made in the FFQ. However, this method is likely to influence the actual intake of participant and would not be an appropriate method when participants are less co-operative or less literate (Cade *et al.*, 2002). Multiple 24-h recalls are more likely to correlate with errors observed with the FFQ, such as recall bias. However, its speed, ease of administration and feasibility for interviewing a large number of subjects in the face of limited resources has made it a popular reference method in FFQ validation studies (Kroke *et al.*, 1999; Nelson, 2003).

A culturally appropriate quantitative food frequency questionnaire (QFFQ) was developed to measure diet in an Inuvialuit population of the Northwest Territories (NWT), Canada (Sharma *et al.*, 2009). The present study aimed to assess the validity of macro- and micronutrient intake as measured by the 142-item QFFQ compared with repeated 24-h dietary recalls.

## Materials and methods

Development of the QFFQ, methods for the 24-h recall collection, as well as recruitment procedures have been described elsewhere (Sharma *et al.*, 2009; Sharma, 2010). 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 Beaufort Delta Health and Social Services Authority Ethics Review Committee. A research license was obtained from the Aurora Research Institute.

### Subjects

The QFFQ was developed based on dietary intake data collected by 24-h recalls in two communities (Communities D and E) in the NWT. The community profiles have been described elsewhere (Sharma, 2010). For this validation study, 64 participants from one of the communities (Community E) were recruited between July and October 2008, although a new random sampling was performed to find households independent of those included in the QFFQ development study. The main food shopper or preparer in each selected household was invited for interview. The inclusion and exclusion criteria for recruiting subjects were the same as those used in QFFQ development (were Inuvialuit, ≥19 years, resided in the community >6 months, not pregnant/lactating) (Sharma *et al.*, 2009). Once participants were enrolled and their consent was obtained, each participant completed the QFFQ and up to three 24-h recalls. The methods of administration of the QFFQ have also been described elsewhere (Sharma, 2010). The QFFQ estimated usual food and drink intake over the past 30 days. The repeated 24-h dietary recalls were administered by trained interviewers. For each participant, recalls were completed on nonconsecutive days, capturing two weekdays and one weekend day. There were one participant with only one and two participants with two 24-h dietary recalls, which were only on weekdays. Three-dimensional food models were used during each interview to help participants accurately estimate their intakes and to prevent reporting errors as a result of misunderstanding of portion sizes (Godwin *et al.*, 2004).

### Analysis

*Computation of daily nutrient intake from QFFQ*

The QFFQ used preweighted food models and household utensils and, for food items without measured portion weights, the Canadian Nutrient File database (10th edition) was used 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, analysis of locally collected recipes, and the USDA National Nutrient Database for Standard Reference 20 (USDA, 2007). For each of the 142 food/beverage items, a record was created in the FCT that contained the nutrient content per 100 g of the food. For QFFQ line items that represented multiple foods (e.g. white bread, including toast, rolls, buns and in sandwiches), the records contained means of the food composition of the relevant foods, weighted by the frequency of consumption based on previously collected data (Sharma *et al.*, 2009). Data extracted from three datasets, including the FCT, QFFQ (frequency and amount of intake) and food/beverage 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 daily nutrient intake from 24-h recalls*

Up to three 24-h recalls were collected from each participant on two weekdays and one weekend day when possible. All recall data were coded, entered and analysed using NUTRIBASE CLINICAL NUTRITION MANAGER, version 7.17 (CyberSoft Inc., Phoenix, AZ, USA). The Canadian food composition tables in NUTRIBASE and locally collected weighed recipes were used for nutrient analysis. 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) for nutrients were computed for both QFFQ and 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 ($\rho$) were adjusted for within-person daily variability (de-attenuated correlation coefficient) by multiplying by an adjustment factor (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 $m$ was the mean number of days covered by the recalls, and the within-person ($\sigma_W^2$) and between-person ($\sigma_B^2$) variances were computed from the days of recall by variance component techniques.

To evaluate the agreement of classification based on the levels of nutrient consumption between the 24-h recalls and the QFFQ, the quartile classifications obtained by both methods were compared. The cut-off point was determined separately for the QFFQ and the 24-h recalls. The percentage in the same and the 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 the repeated 24-h recall was also performed based on the energy-adjusted values of nutrient intakes. These values were computed as the residuals from the regression model to employ as a measure of nutrient intakes independent of total energy intake (Willett, 1998). To assure that subsequent analyses were comparable with results reported for the Dietary Reference Intakes, a subgroup analysis was carried out for two age groups 50 years or younger and those older than 50 years. Bland–Altman plots were used to observe the agreement between the QFFQ and recall, at the individual level. The measurement error was shown by plotting the 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

Sixty-four participants completed the interview for 24-h recalls and the QFFQ (response rate 79%). Four subjects (6.3%) were excluded whose total daily energy reports were >25.1 MJ (6000 kcal). After exclusion, 48 (80.0%) women and 12 (20.0%) men with mean (SD) age of 45 (13) years and 46 (14) years, respectively, were included in the analysis. Means of nutrients intake were computed for 57 participants who completed all three 24-h recalls and for three participants with one or two 24-h recalls (176 days of data).

Table 1 shows the comparison of the two assessment tools for the mean (SD) of energy, total fibre, total sugar, macronutrients and certain micronutrients of interest. Mean intake of all nutrients included in the table were greater for the QFFQ than the 24-h recall.

The crude Spearman correlation coefficient ($\rho$) ranged from 0.10 for total folate to 0.54 for total sugar. Correction for day-to-day variation in dietary intake improved all of the correlations. Amongst macronutrients, the de-attenuated correlation coefficients ranged from 0.33 for protein to 0.45 for carbohydrate. The $\rho$'s range was wider amongst micronutrients where the weakest and strongest de-attenuated correlations were observed for total folate ($\rho = 0.12$) and vitamin C ($\rho = 0.53$), respectively. Adjustment for any effect of energy caused an increase in correlation coefficients between QFFQ and 24-h recall for protein, total sugar, total folate, riboflavin, vitamin D and iron.

Seventy-nine percent of observations for energy, total fibre, total sugar and macronutrients and 72% of observations for micronutrients placed in the same or adjacent quartiles with a mean weighted kappa of 0.28 and 0.19, respectively (Table 2). The mean of misclassification for macro- and micronutrients were 5.3% and 7.6%, respectively.

**Table 1** Correlations between daily intake of energy and nutrients assessed by three 24-h recalls and quantitative food frequency questionnaire (QFFQ) amongst Inuvialuit adults ($n$ = 60) in the Northwest Territories, Canada

| Nutrients | QFFQ Mean (SD) | Recall Mean (SD) | Spearman correlation Crude | De-attenuated | De-attenuated and energy-adjusted |
|---|---|---|---|---|---|
| Energy (MJ*) | 11.28 (4.36) | 8.71 (3.12) | 0.43† | 0.46† | – |
| Carbohydrate (g) | 353 (142) | 272 (111) | 0.43† | 0.45† | 0.39† |
| Total fat (g) | 96 (39) | 69 (25) | 0.40† | 0.44† | 0.24 |
| Protein (g) | 98 (45) | 80 (37) | 0.28†† | 0.33†† | 0.37†† |
| Dietary fibre (g) | 15 (7) | 9 (5) | 0.33†† | 0.35†† | 0.32†† |
| Total sugar (g) | 191 (95) | 145 (76) | 0.54† | 0.57† | 0.62† |
| Total folate (μg) | 336 (129) | 217 (74) | 0.10 | 0.12 | 0.15 |
| Vitamin A (μg RAE) | 689 (333) | 312 (207) | 0.16 | 0.18 | 0.16 |
| Riboflavin (mg) | 4 (2) | 2 (0.87) | 0.29†† | 0.32†† | 0.40† |
| Vitamin C (mg) | 155 (132) | 124 (118) | 0.49† | 0.53† | 0.52† |
| Vitamin D (IU) | 237 (144) | 156 (177) | 0.29†† | 0.33†† | 0.37†† |
| Calcium (mg) | 1143 (551) | 678 (363) | 0.20 | 0.22 | 0.21 |
| Iron (mg) | 19 (8) | 14 (6) | 0.32†† | 0.37†† | 0.55† |
| Zinc (mg) | 15 (7) | 13 (23) | 0.16 | 0.19 | 0.06 |

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

**Table 2** Weighted kappa and cross-classification of nutrient distribution quartiles from 24-h recalls and quantitative food frequency questionnaire, amongst Inuvialuit adults ($n$ = 60) in the Northwest Territories, Canada; weighted kappa was calculated for each nutrient from the observed and expected proportions on 4 × 4 table of frequency

| Nutrients | Cross-classification (%) Same quartile | Adjacent quartile | Opposite quartile | Weighted kappa |
|---|---|---|---|---|
| Energy | 33 | 47 | 7 | 0.26* |
| Carbohydrate | 33 | 45 | 2 | 0.28* |
| Total fat | 39 | 40 | 7 | 0.28* |
| Protein | 35 | 33 | 7 | 0.18† |
| Dietary fibre | 33 | 47 | 7 | 0.26* |
| Total sugar | 38 | 48 | 2 | 0.39* |
| Total folate | 33 | 33 | 10 | 0.12 |
| Vitamin A (RAE) | 27 | 45 | 12 | 0.09 |
| Riboflavin | 35 | 42 | 8 | 0.23* |
| Vitamin C | 37 | 40 | 3 | 0.28* |
| Vitamin D | 38 | 35 | 5 | 0.26* |
| Calcium | 33 | 35 | 8 | 0.15 |
| Iron | 35 | 40 | 7 | 0.23* |
| Zinc | 30 | 38 | 8 | 0.12 |

RAE, retinol activity equivalent.
*$P < 0.01$.
†$P < 0.05$.

Measurement of correlation between the QFFQ and the repeated 24-h recalls for two different age groups (≤50 and >50 years) showed an increase in correlations (from 0.35 to 0.47 for mean de-attenuated $\rho$) for the younger group compared with the analysis for all participants (Table 3). The $\rho$ for all items decreased considerably when only participants >50 years were included in the analysis.

The Bland–Altman plots of energy, macronutrients and some micronutrients of interest illustrated a heterogeneous distribution pattern of the mean of the two measurements and the difference between the two values (Fig. 1). However, the plotted points were predominantly within the 95% limit of agreement for each nutrient. A wide scatter of difference at higher intakes was observed for all plots, which indicated a closer agreement at lower intakes. All plots for macronutrients showed an obvious increase in over-estimation for higher levels of intake.

## Discussion

The present study aimed to estimate the relative validity of the QFFQ adapted for Inuvialuit in the NWT, Canada. Moderate correlation (Zou *et al.*, 2003) was observed between the QFFQ and 24-h recall for energy and nine nutrients under study, comprising those that were assumed to be important to be targeted in a nutrition intervention programme amongst this population. More than two-thirds of the observations resulted in the same or adjacent quartiles.

As the reference tool, the mean of one to three 24-h recalls was used for evaluation of validity of the QFFQ.

**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 Inuvialuit adults ($n$ = 60) in the Northwest Territories, Canada

| | Age ≤50 years ($n$ = 38) | | | Age >50 years ($n$ = 22) | | |
|---|---|---|---|---|---|---|
| Nutrients | Crude | De-attenuated | De-attenuated & energy-adjusted | Crude | De-attenuated | De-attenuated & energy-adjusted |
| Energy | 0.57* | 0.61* | – | NC | NC | – |
| Carbohydrate | 0.46* | 0.48* | 0.37† | NC | NC | 0.39 |
| Total fat | 0.61* | 0.67* | 0.24 | 0.08 | 0.09 | 0.12 |
| Protein | 0.48* | 0.56* | 0.34 | NC | NC | 0.29 |
| Dietary fibre | 0.57* | 0.61* | 0.24 | 0.03 | 0.04 | 0.19 |
| Total sugar | 0.53* | 0.56* | 0.68* | 0.33 | 0.35 | 0.50† |
| Total folate | 0.33 | 0.38 | 0.25 | NC | NC | NC |
| Vitamin A (RAE) | 0.25 | 0.28 | 0.16 | 0.12 | 0.14 | 0.24 |
| Riboflavin | 0.40† | 0.44† | 0.50* | NC | NC | 0.04 |
| Vitamin C | 0.59* | 0.63* | 0.46* | 0.24 | 0.26 | 0.69* |
| Vitamin D | 0.30 | 0.32 | 0.27 | 0.14 | 0.17 | 0.33 |
| Calcium | 0.24 | 0.26 | 0.16 | NC | NC | 0.26 |
| Iron | 0.44* | 0.51* | 0.56* | 0.22 | 0.25 | 0.31 |
| Zinc | 0.24 | 0.29 | 0.12 | NC | NC | NC |

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

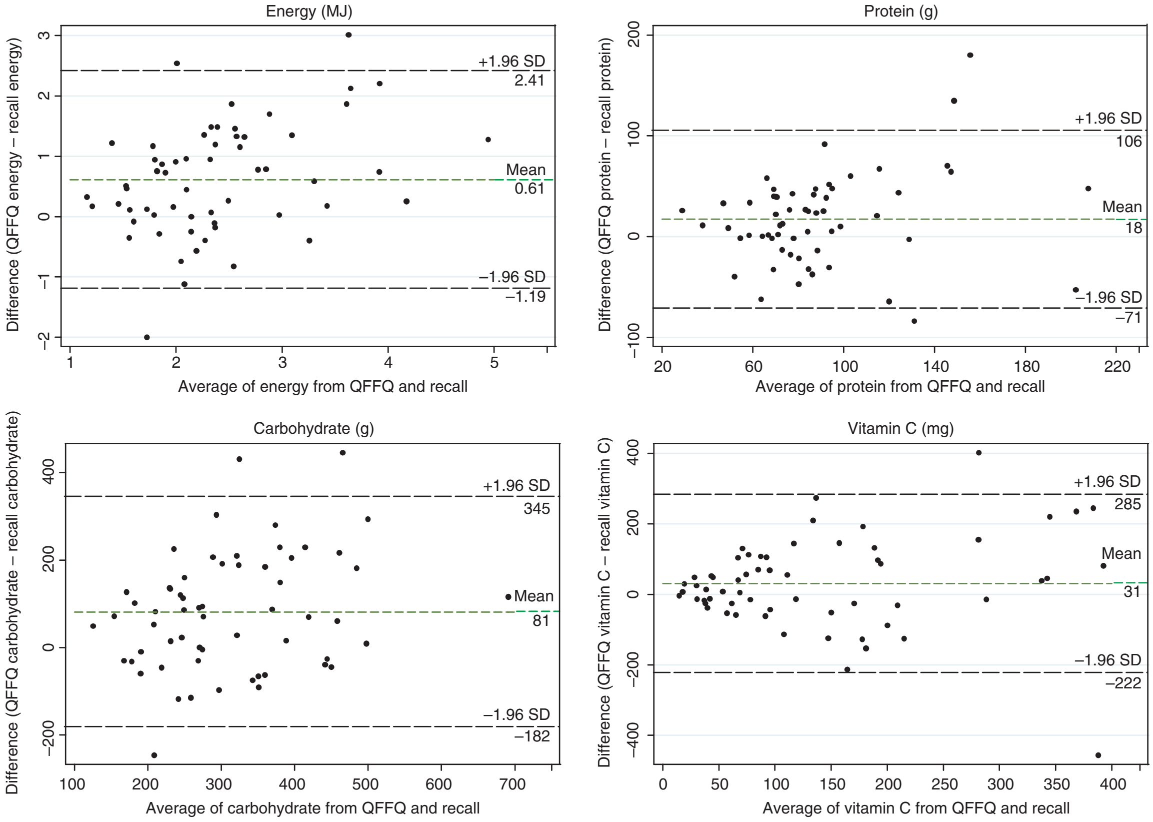


**Figure 1** Bland – Altman plots for energy, carbohydrate, protein and vitamin C. Difference in nutrients intake estimated by quantitative food frequency questionnaire (QFFQ) and 24-h recall plotted against the mean of nutrients intake measured by the two methods for Inuvialuit adults ($n$ = 60) in the Northwest Territories, Canada.

No dietary assessment tool is a gold standard for measuring 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 FFQ are as independent as possible (Nelson, 2003). Major sources of error for FFQs 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, this dietary assessment tool is considered feasible for implementation because it does not place a substantial burden on respondents (Nelson, 2003). Thus, using a mean of multiple 24-h recalls is often chosen as a reference scale for QFFQ validation (Cade *et al.*, 2002).

It has been suggested (Willett, 1998) that within-person variance in intake tends to decrease the correlation between the 24-h recall and QFFQ. To reduce this effect, the crude correlation coefficients were corrected. Compared with a similar QFFQ validation study amongst the Inuit population in Nunavut (Pakseresht & Sharma, 2010), mean de-attenuated $\rho$'s were smaller in the present study (0.41 versus 0.52 for macronutrients and 0.28 versus 0.42 when comparing the same micronutrients).

For nutrients with large ratios of within-person to between-person variance, a few days of recalls are insufficient 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 ratios in the present study were observed for total folate, hence the finding of lower $\rho$'s for this nutrient.

Correlation coefficients between the QFFQ and 24-h recall for protein, total sugar, total folate, riboflavin, vitamin D and iron increased after adjustment for energy. However, after energy adjustment, $\rho$'s decreased for other nutrients under study. Adjustment for energy would increase the correlation coefficients when the variability in nutrient intake is related to energy intake, although they would decrease when the nutrient variability depends on systematic errors of over-estimation or under-estimation (Willett, 1998). Such disproportional results may affect the concordance between two dietary instruments (World Health Organization, 2003). Twenty percent of the food items included in the QFFQ have low nutritional value (carbonated drinks, sugar and fried foods) and high energy value, thereby favouring a tendency towards exaggerating the diet's nutrient content. The QFFQ was developed to include both traditional and shop-bought foods because the consumption of these would be monitored over time. Increased correlation after adjusting for energy has been reported previously (Willett *et al.*, 1985; Cardoso *et al.*, 2001; Wengreen *et al.*, 2001); however, some studies (Martin-Moreno *et al.*, 1993; Jackson *et al.*, 2001; Kim *et al.*, 2002; Fornés *et al.*, 2003; Deschamps *et al.*, 2009) reported attenuation of correlation coefficients after adjustment.

The cross-classification procedure is able to capture differential under- and over-reporting in intake (Friis *et al.*, 1997), whereas correlation analysis does not. In the present study, more than 70% of observations placed in the same or adjacent quartiles for estimation of nutrient intakes, excluding protein, total folate, calcium and zinc, by the QFFQ and 24-h recall. The proportions of complete and relative agreement in the present study are comparable with those reported for Nunavut in Canada (Pakseresht & Sharma, 2010) and by other studies (van Liere *et al.*, 1997; Slater *et al.*, 2003; Deschamps *et al.*, 2009).

An inconsistent pattern in the range of intakes for energy, carbohydrate, protein and vitamin C was observed in the Bland–Altman plots. Nevertheless, the agreement between the two methods was better for subjects who consumed less. This indicates a possible over-reporting on the QFFQ for those subjects who had higher intake. A similar finding was observed in a QFFQ validation study for Nunavut (Pakseresht & Sharma, 2010).

Measurement of correlation between the QFFQ and 24-h recall for subjects ≤50 years revealed a clear improvement compared with the general model of analysis. The two dietary tools showed a weak correlation for most of the nutrients amongst subjects >50 years of age. This finding indicates consistent differences in the elders' ability to complete questionnaires well, probably as a result of the elders' lack of familiarity with shop-bought foods listed on the QFFQ. The diet of the elders is mostly traditional and considerably different from those of younger age groups. 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 the validation of a questionnaire. 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 additional 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 142-item QFFQ used in the present study is an acceptable length. Moreover, it has been designed to be culturally appropriate, contain local and traditional food items, and utilise appropriate portion sizes. The participants were asked to recall daily dietary intakes over 30 days. Thus, seasonal variation is not a major factor in the present study.

In conclusion, the developed QFFQ was able to estimate daily intakes of nutrients, particularly macronutrients and vitamin C, for Inuvialuit adults. The QFFQ can be used to assess dietary adequacy and contribution of foods to nutrients of interest pre- and post-intervention. In addition, it can be used to identify dietary risk factors for chronic disease amongst this population.

## 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, the Government of the Northwest Territories Department of Health and Social Services, Health Canada, the Public Health Agency of Canada and Northwest Territories and Nunavut Public Health Association. SS developed the conception and design of this 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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