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ORIGINAL RESEARCH

Development and evaluation of a food frequency questionnaire to assess nutrient intakes of adult women in New Zealand

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Abstract

Aim: In New Zealand, there are few adequate food frequency questionnaires for assessing dietary intake. This study aimed to develop and assess the relative validity of a multi-nutrient, culturally appropriate, semi-quantitative food frequency questionnaire for use in young adult New Zealand women (the New Zealand Women's Food Frequency Questionnaire (NZWFFQ)).

Methods: Women (n = 110) aged 16–45 years of Māori, Pacific or European ethnicity completed a NZWFFQ assessing dietary intake over the previous month, and a 4-day weighed food record. Relative validity was evaluated by comparing nutrient intakes from the NZWFFQ with the food record using Spearman's rank correlation coefficients, cross-classification, the weighted kappa statistic and Bland–Altman analysis.

Results: Nutrient intake was higher from the NZWFFQ compared with the food record for all nutrients (range: 1%–64% difference) except alcohol (−16% difference). Energy-adjusted correlations ranged from 0.23 to 0.67 (average 0.48). Correct classification into same and adjacent quartiles was over 70% for all nutrients except folate and vitamin D. Gross misclassification into opposite quartiles ranged from 1% (monounsaturated fat, magnesium, calcium) to 10% (iron). The weighted kappa showed poor agreement for vitamin D and folate, fair agreement for most nutrients, and moderate agreement for fibre, vitamin E, magnesium, calcium and phosphorus.

Conclusions: The NZWFFQ overestimated intake of nearly all nutrients. While not suitable for assessing absolute intake, the NZWFFQ is suitable for ranking individuals based on nutrient intake demonstrating reasonable relative validity for this purpose.

Key words: diet questionnaire, dietary assessment, validity, women.

Introduction

Rates of obesity are increasing in New Zealand, with levels of obesity particularly high in Pacific Island and Māori women.[1] Paradoxically, suboptimal micronutrient intake and deficiency are also a problem.[2] For example, in the most recent national nutrition survey 68.4% of women 19–30 years had inadequate calcium intakes and 5.2% had iron deficiency. In order to further establish associations between dietary intake, health and disease, and to evaluate impact of intervention strategies, it is important that dietary intake is appropriately assessed. Traditionally, food records have been the preferred method to accurately assess dietary intakes, however, they have a large participant and researcher burden.[3] Therefore, when investigating the dietary intake of large populations, the food frequency questionnaire (FFQ) is commonly used.[3,4] Typically FFQs are designed to rank individuals according to nutrient intakes, rather than to assess absolute intakes.[4,5] As dietary intake varies across time and population groups,[6] FFQs need to be current, specific and culturally appropriate for the population in which they are intended to be used. Prior to being used, it is vital that a FFQ is evaluated in the population of interest,[6] assessing

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relative validity by comparison with an appropriate reference dietary assessment method.[3,6]

Although FFQs have previously been developed and validated to evaluate multi-nutrient intake in New Zealand adults,[5,7–10] four out of five were developed over 15 years ago. These are no longer suitable due to changes in the dietary intake of New Zealanders.[11] The most recent FFQ developed for New Zealand adults included 154 food items and was validated against an 8-day food record and biomarkers in adult males and females primarily of European ethnicity.[5] It demonstrated good validity for ranking individual's nutrient intake, however, it's applicability for use in other ethnic groups may be limited.

The present study aimed to develop and assess the relative validity of a culturally appropriate multi-nutrient FFQ for use in young adult women of Māori, Pacific and European ethnicity living in New Zealand as part of the Women's EXPLORE (Examining Predictors Linking Obesity Related Elements) study.

Methods

The New Zealand Women's Food Frequency Questionnaire (NZWFFQ) validation study was undertaken as part of the EXPLORE study[12] at Massey University (MU), Auckland. Ethical approval for the EXPLORE study was obtained from MU Human Ethics Committee, Southern A, Application 13/13. Written informed consent was obtained from all participants.

The NZWFFQ was designed to assess usual food intake including energy, macronutrient (protein; fat: total, saturated, polyunsaturated and monounsaturated fat; carbohydrate: total, total sugar, fibre), micronutrient (vitamins: A, C D, E, B1, B2, B3, B6, B12, folate; minerals: zinc, calcium, iron, phosphorus, magnesium) and alcohol intakes over the previous month. Development of the NZWFFQ commenced with modification and extension of the 1997/1998 New Zealand Adult Nutrition Survey food list.[13] Further additions were made using the 2008/2009 New Zealand Adult Nutrition Survey results.[2] Two cultural advisors (one of Māori and one of Pacific ethnicity) reviewed the NZWFFQ to ensure culturally appropriate foods were included. Examples of foods added included energy drinks, seeds, almond milk, and 'ready to drink' alcoholic beverages.

The final NZWFFQ comprised of 220 identified food items, under 16 food categories: dairy, bread, breakfast cereals and porridge, starchy foods, meat, poultry, fish and seafood, fats and oils, eggs, legumes, vegetables, fruit, drinks, dressings and sauces, miscellaneous and other. Within the food categories, foods were grouped according to composition (e.g. whole grain *vs* white bread), nutrient content (e.g. whole *vs* low fat milk) and frequency of consumption (e.g. bananas grouped separately from other fruit due to a high frequency of consumption).[13] Supplementary questions were included within food categories to assess: usual additions to foods during cooking, food preparation and cooking methods and food types. A semi-quantitative format was used, with serving sizes based on amounts commonly purchased or eaten based on those in the New Zealand food composition tables.[14] For food items, two quantity descriptions were used to enhance familiarity of serving sizes. For example, 'palm size' and 'half a cup' for meat. Participants selected the frequency category best describing their intake from nine options ranging from 'never' to 'four plus times per day'. A final open-ended question allowed participants to add any foods consumed not included in the NZWFFQ.

The NZWFFQ was pilot tested among 60 MU nutrition students who were predominantly female, 18–44 years, and of European, Māori or Pacific descent. Changes were made in terms of readability, clarity and a few foods (e.g. quinoa) were added to the NZWFFQ. The NZWFFQ was administered using SurveyMonkey and took approximately 25 minutes to complete.

A convenience sample of female participants aged 16–45 years of European, Māori or Pacific ethnicity were recruited from the general population in Auckland, New Zealand for the EXPLORE study.[12] Exclusion criteria included being post-menopausal, currently pregnant or breast-feeding, or having a chronic disease. Recommendations for the validation of dietary assessment methods suggest a sample size greater than 100 participants.[3,15] Recruitment occurred between July 2013 and May 2014. Women interested in participating completed a screening questionnaire based on study eligibility criteria.[12] Weight, height and body fat percentage (bioelectrical impedance analysis) were assessed to ensure participants met specific body composition profiles for EXPLORE: body mass index (BMI) <25 kg/m^2, body fat (BF) ≥22%–<30%; BMI <25 kg/m^2, BF ≥30% and BMI ≥25 kg/m^2, BF ≥30%.

During another appointment at the MU Human Nutrition Research Unit, eligible participants had weight and height measured according to a standardised protocol[16] and completed the NZWFFQ. Standardised instructions were provided and a researcher was available to answer questions while the NZWFFQ was being completed. Participants watched an instruction video developed by MU dietitians and nutritionists for completing a 4-day weighed food record (4d-WFR). The DVD detailed how to describe foods including types of food, brands names and cooking methods. All participants were given a food record booklet, electronic scales (Tanita KD-200), and a supplementary booklet[17] to assist food recording during occasions where scales could not be used (e.g. eating out). Participants were allocated the four consecutive days following their appointment including at least one weekend day for completing the 4d-WFR. Data collection covered all days of the week. The importance of not changing usual eating habits was emphasised, and participants were asked to record food at the time of eating. Completed 4d-WFRs were reviewed by a research team member. Where data were incomplete, the participant was contacted to provide further detail. Data were collected between August 2013 and July 2014, covering all four seasons.

Data from the NZWFFQ and 4d-WFR were entered into Foodworks version 7 (Xyris Software 2013, Queensland, Australia) by trained nutritionists. Foodworks uses the New Zealand Food Composition Database and FOODfiles[18] to determine nutrient intakes. Each food item on the NZWFFQ was matched to a food item in Foodworks, after discussion by research team members. Generic non-branded food items were used where possible. In some

cases, one food item in the NZWFFQ covered multiple related foods (e.g. onions, leeks, celery) and one food item was chosen to represent the nutrient content of these food items (e.g. onions). Supplementary questions on the NZWFFQ assisted with Foodworks data entry. For example, 'chicken breast, lean and trimmed' was selected for participants who trimmed the fat off chicken. Additional foods not included in the NZWFFQ from the final open-ended question were entered separately into Foodworks. The online nature of the NZWFFQ ensured no missing answers.

Foods from the 4d-WFR were entered into Foodworks using the closest food match possible. When food items were absent from the database, a similar composite item was selected. For homemade recipes, individual ingredients were entered as a 'recipe' taking into account the number of serves it provided. Conversion factors were used for raw ingredients, to ensure the cooked proportion was used for analysis. The mean of 4 days of reporting was used to obtain daily nutrient intakes for each participant. Participants were excluded from analysis who reported an energy intake of <2100 kJ (500 kcal) or >21 000 kJ (5000 kcal) per day from either dietary assessment tool.[19] Vitamin and mineral supplements were not included in the NZWFFQ, nor entered into Foodworks from the 4d-WFR.

Statistical analyses were conducted using SPSS, version 24.0 (IBM Corp, Armonk, NY, USA). A *P*-value of <0.05 (two-tailed) was considered statistically significant. Data were checked for normality using Kolmogorov–Smirnov tests and histograms. Descriptive statistics were reported as means (SD) for parametric data, medians (25th, 75th percentile) for non-parametric data and numbers and percentages for categorical data. To assess relative validity of the NZWFFQ, nutrient intakes were compared with corresponding 4d-WFR data. Data from both the NZWFFQ and the 4d-WFR were adjusted for energy intake using the residual method to produce a nutrient measure not correlated with energy intake.[3,20] Using this method, energy-adjusted nutrient intakes were computed as residuals from the regression model, with absolute nutrient intake as the dependent variable and total energy intake as the independent variable.[3]

Spearman rank correlation coefficients were used to assess the association of each nutrient between the NZWFFQ and 4d-WFR. Nutrient intakes were divided into quartiles for both the NZWFFQ and 4d-WFRs. Participants were classified as being in the same and adjacent quartiles and extreme quartiles (gross misclassification). Cross-classification agreement was further investigated using the weighted kappa (κ)-statistic.[21] The formula used was: $\kappa = Pr(a) - Pr(e)/1 - Pr(e)$, where Pr(a) is the observed proportion of agreement between the NZWFFQ and 4d-WFR and Pr(e) is expected proportion of chance agreement. Using the formula, correct classification into same quartile was given a weight of 1; two-thirds for adjacent quartiles; one-third for adjacent plus one quartile and zero for opposite quartiles. Agreement levels for the κ-statistic were: very good (>0.80); good (0.61–0.80); moderate (0.41–0.60); fair (0.21–0.40) and poor (<0.20).[22] These statistical tests were undertaken on both raw and energy-adjusted data.

Agreement across the range of intakes was assessed using Bland–Altman plots, where the difference in intake was plotted against mean intake for each nutrient from the NZWFFQ and 4d-WFR.[23] Mean differences were calculated and the limits of agreement determined as the mean difference ±1.96SD. To investigate the slope of bias in the Bland Altman plots, linear regression analysis was undertaken (difference in intake as the dependent variable; mean intake as the independent variable).

Results

Of the 135 women who participated, 111 completed both the NZWFFQ and 4d-WFR, and 110 participants were included in the analysis. One participant who reported an energy intake of 42 026 kJ per day (NZWFFQ) was excluded. Most were of European ethnicity (Table 1).

Mean energy and all nutrient intakes, except alcohol, were higher from the NZWFFQ compared to the 4d-WFR (Table 2). Correlations ranged from 0.11 (iron) to 0.59 (saturated fat), with an average correlation of 0.37. Energy-adjusted correlations ranged from 0.23 (vitamin D) to 0.67 (magnesium), with an average correlation of 0.48. Correlation coefficients of 0.5–0.7 were observed for total fat, saturated fat, polyunsaturated fat, monounsaturated fat, alcohol, riboflavin, vitamin C, vitamin E, magnesium, calcium and phosphorus. The majority of nutrients had correlations of 0.3–0.5. Vitamin D and folate had correlations between 0.1 and 0.3.

The percentage of participants classified into the same and adjacent quartiles ranged from 62% (iron) to 86% (saturated fat), with an average of 74% (Table 3). Over 40% of participants were classified into the same quartile for three nutrients. Gross misclassification into the opposite quartile ranged from 3% (saturated fat) to 10% (iron) (average 6%). Following adjustment for energy intake, correct classification into same and adjacent quartiles improved and ranged from 66% (vitamin D) to 88% (saturated fat) (average 80%), and over 40% of participants were classified into the same quartile for 15 of the nutrients. Gross misclassification into opposite quartiles ranged from 1% (for monounsaturated fat, magnesium, calcium) to 10% (iron) (average 5%). Using the weighted kappa statistic (κ), most nutrients had

Table 1 Participant characteristics (n = 110)

Characteristics	*Mean (SD), median (25th, 75th percentile) or n (%)*
Age (years)	32.4 (7.6)
Ethnicity	
European	89 (80.9)
Māori	13 (11.8)
Pacific	8 (7.3)
Body mass index (BMI, kg/m^2)	23.2 (21.1, 26.1)
Normal BMI: 18.5–24.9	73 (66.4)
Overweight and obese BMI: ≥25	37 (33.6)

Table 2 Mean daily nutrient intakes from the NZWFFQ and 4d-WFR and correlation coefficients (n = 110)

Nutrients	*4d-WFR, daily intake (mean (SD))*	*NZWFFQ, daily intake (mean (SD))*	*Percentage difference between NZWFFQ and 4d-WFR*	*Correlation coefficients*[(a)]		*Correlation coefficients*[(a)]	
				Unadjusted r[(b)]	P-*value*	*Adjusted* r[(c)]	P-*value*
Energy (kJ)	7845 (1716)	8936 (2741)	14	0.32	0.001	—	—
Protein (g)	85.7 (24.8)	98.8 (34.0)	15	0.32	0.001	0.49	<0.001
Total fat (g)	75.9 (23.3)	86.8 (34.0)	14	0.50	<0.001	0.54	<0.001
Saturated fat (g)	27.9 (10.8)	34.4 (16.4)	23	0.59	<0.001	0.61	<0.001
Polyunsaturated fat (g)	12.5 (6.2)	13.1 (5.1)	5	0.43	<0.001	0.53	<0.001
Monounsaturated fat (g)	27.7 (9.0)	29.6 (11.6)	7	0.47	<0.001	0.58	<0.001
Cholesterol (mg)	252 (141)	293 (152)	16	0.48	<0.001	0.48	<0.001
Carbohydrate (g)	200 (57)	230 (75)	15	0.38	<0.001	0.49	<0.001
Total sugars (g)	94 (31)	120 (43)	28	0.37	<0.001	0.44	<0.001
Alcohol (g)	9.2 (13.7)	7.7 (9.7)	–16	0.52	<0.001	0.55	<0.001
Dietary fibre (g)	26.3 (16.3)	30.3 (8.8)	15	0.24	0.01	0.43	<0.001
Thiamine (mg)	1.4 (0.7)	1.8 (0.9)	29	0.48	<0.001	0.46	<0.001
Riboflavin (mg)	2.1 (0.7)	2.7 (1.0)	29	0.37	<0.001	0.51	<0.001
Niacin (mg)	17.8 (6.1)	22.9 (8.2)	29	0.26	0.01	0.36	<0.001
Vitamin C (mg)	99.3 (55.7)	157.5 (74.0)	59	0.49	<0.001	0.56	<0.001
Vitamin D (μg)	4.4 (3.4)	4.7 (2.8)	7	0.41	<0.001	0.23	0.01
Vitamin E (mg)	10.5 (4.8)	13.5 (5.2)	29	0.35	<0.001	0.59	<0.001
Vitamin B6 (mg)	2.1 (1.0)	2.5 (0.9)	19	0.36	<0.001	0.47	<0.001
Vitamin B12 (μg)	4.4 (4.9)	4.9 (2.5)	11	0.38	<0.001	0.36	<0.001
Total folate (μg)	403 (168)	446 (161)	11	0.39	<0.001	0.26	0.01
Total vitamin A equivalents (μg)	943 (935)	1544 (582)	64	0.26	0.01	0.38	<0.001
Magnesium (mg)	369 (163)	417 (117)	13	0.28	0.004	0.67	<0.001
Calcium (mg)	943 (340)	1255 (541)	33	0.49	<0.001	0.65	<0.001
Phosphorus (mg)	1498 (484)	1795 (575)	20	0.28	0.003	0.59	<0.001
Iron (mg)	13.0 (4.7)	13.1 (4.0)	1	0.11	0.27	0.33	<0.001
Zinc (mg)	10.6 (3.5)	12.3 (4.1)	16	0.23	0.01	0.45	<0.001

4d-WFR, four-day weighed food record; NZWFFQ, New Zealand Women's Food Frequency Questionnaire.
(a) Spearman correlation coefficients.
(b) Unadjusted raw dietary data.
(c) Adjusted for energy intake.

fair agreement (κ = 0.21–0.40), and saturated fat had moderate agreement (κ = 0.41–0.60). After energy intake adjustment, total fat, vitamin E, magnesium, calcium and phosphorus had moderate agreement. Bland–Altman plots can be observed in Figure S1. It can be seen, for example, that as the mean intake for monounsaturated fat from the NZWFFQ and 4d-WFR increased, the difference in intake between the two methods also increased. The slope of the bias was statistically significant for all nutrients except for cholesterol, vitamins B6 and E, folate, phosphorus, iron and zinc indicating variation in the agreement between methods across the mean intake of these nutrients.

Discussion

This study investigated the relative validity of a FFQ designed to assess nutrient intake in young adult New Zealand women. Overall, the NZWFFQ was found to be appropriate for ranking individual's dietary intake, but overestimated nutrient intake compared to the 4d-WFR. The relative validity of the NZWFFQ improved following adjustment for energy intake.

Correlation coefficients between the NZWFFQ and 4d-WFR ranged from 0.11 to 0.59. These are similar to validity correlations found in other New Zealand studies examining the validity of FFQs (0.11–0.74,[5] –0.03 to 0.48,[7] –0.18 to 0.50,[8] 0.36–0.84[9] and 0.21–0.74[10]) and in similar population groups internationally.[19,20,24] Following adjustment for energy intake, correlations improved (0.23–0.67) for most nutrients. Most validation studies use correlation coefficients. However, correlation coefficients only measure the degree to which dietary assessment measures are associated, and do not measure absolute agreement. Nutrient intakes were higher from the NZWFFQ compared to the 4d-WFR, with differences ranging from –16% to 64%. However, 16 nutrients differed by less than 20%. In other New Zealand studies most,[5,7,9,10] but not all FFQs overestimated nutrient intakes when compared to food records with differences ranging from –62% to 38%,[8] –16% to 70%,[5] –15% to 41%,[10] –8% to 9%[9] and 17% to 84%[7] for the same nutrients as the NZWFFQ. The extensive list of foods in the NZWFFQ may have contributed to the overestimation of nutrients. Alcohol was the only nutrient for which intake was higher from the 4d-WFR compared to

Table 3 Cross-classification and weighted kappa between the NZWFFQ[a] and 4d-WFR (n = 110)[b]

	Unadjusted[c]				*Adjusted*[d]			
Nutrients	*Correctly classified into the same quartile (%)*	*Classified into the adjacent quartile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*	*Correctly classified into the same quartile (%)*	*Classified into the adjacent quartile (%)*	*Grossly misclassified (%)*	*Weighted kappa statistic*
Energy	32.7	38.2	7.3	0.17	—	—	—	—
Protein	31.8	43.6	7.3	0.21	45.5	36.3	5.5	0.38
Total fat	39.1	40.0	3.6	0.32	50.0	34.5	3.6	0.45
Saturated fat	47.3	39.1	2.7	0.46	39.1	49.1	3.6	0.40
Polyunsaturated fat	40.9	33.6	4.5	0.28	44.5	34.6	1.8	0.38
Monounsaturated fat	36.4	44.5	4.5	0.31	40.9	42.7	0.9	0.40
Cholesterol	35.5	41.8	3.6	0.27	33.6	45.5	3.6	0.28
Carbohydrate	33.6	46.4	6.4	0.27	39.1	38.2	3.6	0.31
Total sugars	33.6	44.6	6.4	0.26	40.9	38.2	5.5	0.32
Dietary fibre	34.5	35.5	8.2	0.17	42.7	38.2	5.5	0.35
Thiamine	41.8	36.4	5.5	0.33	37.3	41.8	5.5	0.29
Riboflavin	34.5	40	5.5	0.23	40.9	41.8	5.5	0.35
Niacin	32.7	35.5	8.2	0.14	45.5	30.9	9.1	0.31
Vitamin C	31.8	47.3	3.6	0.26	40.0	40.9	2.7	0.35
Vitamin D	37.3	30.9	3.6	0.20	31.8	34.6	9.1	0.12
Vitamin E	32.7	39.1	6.4	0.19	42.7	43.7	3.6	0.41
Vitamin B6	37.3	37.2	6.4	0.25	46.4	29.1	3.6	0.35
Vitamin B12	35.5	36.3	3.6	0.22	40.9	32.7	7.3	0.26
Total folate	37.3	35.4	4.5	0.24	27.3	41.8	7.3	0.12
Total vitamin A equivalents	26.4	31.8	7.3	0.10	39.1	35.4	4.5	0.28
Magnesium	38.2	40.0	9.1	0.28	47.3	39.1	0.9	0.47
Calcium	39.1	40.9	4.5	0.32	46.4	40.9	0.9	0.47
Phosphorus	21.8	49.1	7.3	0.09	48.2	34.5	3.6	0.42
Iron	33.6	28.2	10.0	0.08	37.3	37.2	10.0	0.22
Zinc	27.3	40.9	8.2	0.10	34.5	45.5	5.5	0.28

4d-WFR, four-day weighed food record; NZWFFQ, New Zealand Women's Food Frequency Questionnaire.
[a] 28 participants in quartiles 1 and 4, 27 participants in quartiles 2 and 3.
[b] Alcohol was not divided into quartiles as more than 25% of participants (n = 36) consumed no alcohol (4d-WFR).
[c] Unadjusted raw dietary data.
[d] Adjusted for energy intake.

the NZWFFQ (16% difference). It is possible that alcohol intake is more difficult to estimate retrospectively (NZWFFQ) or the weighing period of 4 days was not adequate to capture episodic behaviour. Bland–Altman and linear regression analysis demonstrated that differences between the NZWFFQ and 4d-WFR were significantly dependent on the mean intake for several of the nutrients. The plots also show outliers attributed to a small number of participants where differences between the NZWFFQ and 4d-WFR were large.

While the NZWFFQ appears to overestimate the absolute intake of most nutrients, the ability of the NZWFFQ to rank individual's nutrient intakes and distinguish between low versus high intakes is more relevant when investigating associations between dietary intake and health outcomes. For all nutrients, the majority of participants (61.8–86.4%) were correctly classified to within one quartile when comparing the NZWFFQ with the 4d-WFR. Gross misclassification into the opposite quartile ranged from 2.7% to 10.0%. These results improved following energy adjustment (correct classification (over 40%) into the same quartile for 15 nutrients compared with three nutrients prior to energy adjustment; correct classification to within one quartile 66.3–88.2%; gross misclassification 0.9–10.0%). Correct classification to within one quartile was over 70% for all nutrients with the exception of folate and vitamin D. These findings are similar to another New Zealand validation study using quartiles (65.9–97.0% correctly classified to within one quartile).[6] Other New Zealand validation studies have used tertiles[7] and quintiles[8,10] to compare dietary assessment methods making comparisons difficult. For example, using quintiles instead of tertiles decreases the proportion of participants correctly classified and misclassified. The weighted kappa statistic was used to overcome the effect of chance when using cross-classification. Sixteen nutrients had fair and one had moderate agreement, which improved after energy

adjustment to 17 with fair and five with moderate agreement. Values ranged from 0.12 (folate and vitamin D) to 0.47 (magnesium, calcium), similar to the results of Masson *et al*. (–0.08 to 0.66).[22]

There were several strengths associated with this study. A range of statistical methods were used to evaluate the NZWFFQ as recommended.[6,15] The online nature of the NZWFFQ ensured complete data capture and all food records were reviewed for completeness. Food records were undertaken for 4 days which meets recommendations for the optimal duration of food records during validation studies.[25] However, it has been suggested that days of food recording should not be consecutive,[3] in order to obtain a better estimate of day-to-day variations in dietary intake.[5] Furthermore, more than 4 days of recording are required to accurately assess intakes of nutrients such as iron.[26]

All dietary assessment methods based on self-report involve varying levels of measurement error.[27] As the errors associated with estimating intake via food records and FFQs are from different sources, they tend to have the least correlated errors,[3] and therefore a food record was used as the reference method, similar to other New Zealand studies.[6–10] However, weighing every food item increases participant burden[3] and can lead to under-reporting,[28] or changes to food intake behaviour such as selection of foods that are less difficult to weigh, thereby deviating from normal patterns of food intake. One participant with an implausible intake (>21 000 kJ per day) was not considered in the analysis. The remaining participants reported energy intakes between 2100 and 21 000 kJ per day from both dietary assessment methods. As intake of several foods and nutrients is associated with energy,[3] it is recommended that self-reported energy intake is used to adjust other self-reported nutrients for energy.[27] The relative validity of the NZWFFQ improved when intakes were adjusted for energy intake.

There are a number of limitations with this study. The NZWFFQ did not consider micronutrient supplementation. Evaluating the validity of any dietary assessment method requires testing on a study sample that represents the population of interest (e.g. age, gender and ethnicity). The study sample was a convenience sample of over 100 participants recruited for the EXPLORE study,[12] which may result in selection bias. Volunteers may be different from the overall population on a range of characteristics that may impact on dietary reporting, such as increased interest in health and nutrition. In fact, participants had a lower BMI than the New Zealand population[1] suggesting some differences. There was a small representation of Māori and Pacific participants, however, this representation was comparable to the New Zealand population.[29] The small sub-samples meant that validity could not be evaluated in each ethnicity separately, and the results largely reflect responses of participants identifying as New Zealand European (81% of the sample). This is important as dietary assessment methods may perform differently across cultural groups.[3,6,9] For example, in New Zealand Metcalf *et al*.[9] found differences between Māori, Pacific and European populations when comparing a FFQ with a 3-day food record. Lower validity in subcultures may be due to limited or absent culturally relevant food items in the FFQ food list. Culturally relevant foods were included in the NZWFFQ, however, further research is needed to assess the use of the NZWFFQ in larger groups of Māori and Pacific populations, and other population sub-groups. Finally, the reproducibility of the NZWFFQ should be assessed to determine whether similar responses are yielded from subsequent administrations.[3,6]

The NZWFFQ was a 220-item, multi-nutrient FFQ which demonstrated reasonable relative validity for ranking individual's nutrient intake when compared to a 4d-WFR. However, like other FFQs the NZWFFQ tended to overestimate nutrient intake. Future studies using the NZWFFQ should adjust for energy intake to reduce dietary assessment error when investigating associations between dietary intake and health outcomes.

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Conflict of interest

The authors have no conflicts of interest.

Authorship

The study and food frequency questionnaire was designed by KLB, ZLH, SAM and RK; data were collected by KLB, ZLH and RK; data were analysed by KLB and ZLH; data interpretation was undertaken by KLB, ZLH and RK; and manuscript preparation was undertaken by KLB and ZLH. All authors revised and are in agreement with the manuscript. The content has not been published elsewhere. Thank you to Wendy O'Brien and Shakeela Jayasinghe for management of participant recruitment, and Adrianna Hepburn and Sarah Philipsen for assistance with data entry.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Figure S1 Bland–Altman plots for all nutrients. The middle line represents the mean difference between the NZWFFQ and the 4d-WFR and the dotted line. The dotted lines represent the limits of agreement (mean difference ± 1.96SD).