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Evaluating a novel dietary diversity questionnaire to assess dietary diversity and adequacy of New Zealand women

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ABSTRACT

Objectives: We sought to develop and evaluate the relative validity of a dietary diversity questionnaire (DDQ) that reflects food-group diversity, food variety, and micronutrient adequacy among New Zealand women.
Methods: A cross-sectional study included New Zealand women (Auckland based; ages 16–45 y, n = 101), completing a 7-d DDQ and 4-d weighed food record (reference method). The relative validity of the DDQ was evaluated by correlating nutritious and discretionary dietary diversity scores (DDSs; number of food groups) and food-variety scores (number of foods), calculated from both methods. The dietary mean adequacy ratio (MAR; micronutrient intakes relative to estimated average requirements) was calculated from the weighed food record and correlated to dietary diversity and food-variety scores from the DDQ to assess construct validity. Cross-tabulation was used to explore dietary diversity measures versus adequacy ratios. Significance was set at $P < 0.05$.
Results: The median (interquartile range) DDSs (maximum 25) from the DDQ—23 (21–23)—and the weighed food record—18 (17–19)—were significantly correlated ($r_s = 0.33$, $P < 0.001$), as were the food-variety scores (maximum 237)—respectively, 75 (61–87) and 45 (37–52) ($r_s = 0.22$, $P < 0.03$). A mean (± SD) MAR of 0.94 ± 0.04 suggested a near-adequate diet, but one-third of foods consumed were from discretionary sources. Nutritious DDS was significantly correlated with MAR for micronutrients ($r_s = 0.20$, $P \leq 0.05$). An inverse trend was observed between discretionary DDS and MAR.
Conclusions: The DDQ is a quick, low-burden tool for describing nutritious and discretionary dietary diversity reflecting micronutrient adequacy in high-income settings. It requires further validation across different time frames, population groups, and settings.

Introduction

Consuming a variety of foods as part of a healthy diet increases the range of nutrients consumed to meet essential nutrient requirements. Including a variety of food from each major food group further increases the likelihood of meeting food-based dietary guidelines. Diverse diets are associated with improved health outcomes such as reduced mortality, cancer, and cardiovascular disease [1–5]. There is not one single food or food group that provides all the necessary nutrients for health. Foote et al. [6] reported in 2004 that energy intake was strongly correlated with dietary variety, food-group intakes, and nutrient adequacy. In adults, consuming different food items in a day significantly increased the mean probability of nutrient adequacy, even after adjusting for energy intake and number of servings. This finding supports the concept that choosing a greater variety of foods and food groups results in a greater probability of a nutritionally adequate diet [6,7]. Most international (and New Zealand) food and nutrition guidelines recommend consumption of a variety of foods [8–11]. Dietary diversity has been defined as the variety within

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and between food groups: the number of different food groups (assessed as dietary diversity score; DDS) or different foods (food-variety score; FVS) consumed over a certain time period [12–14]. In low-income countries with poor diet quality (nutrient adequacy), dietary diversity assessments have been undertaken to reflect the variety of food accessible to individuals or households, describing the quality and nutritional adequacy of individual diets [1,12].

Dietary diversity questionnaires (DDQs) are simple to administer, require relatively low literacy skills, and impose a low participant burden relative to traditional dietary assessment methods [12,15,16]. Limited evidence suggests that dietary diversity measures can be used to reflect nutrient adequacy in high-income countries [6]; however, few tools are available to assess dietary diversity (variety within and between food groups).

New Zealand (NZ) has among the highest rates of obesity worldwide; 30.9% of the population ages ≥ 15 y have a body mass index (BMI) ≥ 30.0 kg/m^2 (categorized as obese). Obesity is particularly prevalent among Māori (47.9%) and Pacific (63.4%) people, and 1.8 times more prevalent in adults living in more deprived areas [17]. Globally, over the years the prevalence of obesity has increased in women, and is projected to rise to 21% by 2025 [18]. Among NZ women however, current figures (31.7%) have already surpassed this [17]. Alongside this, NZ has high availability of food and excessive intakes of discretionary foods. For example, for younger women, discretionary food has been shown to contribute to total energy intake in equal proportions as some nutritious foods: non-alcoholic beverages (7.0%), alcoholic beverages (4.9%), sugar and sweets (4.7%), cakes and muffins (4.1%), and pies and pastries (2.9%). Total protein also came 3.0% from pies and pastries, 2.6% from non-alcoholic beverages, and 2.2% from cakes and muffins. Total fat contribution was highest from potatoes, kumaras (sweet potato), and taro (8.2%), due to cooking method. Total carbohydrates also came 12% from non-alcoholic beverages, 7.6% from sugar and sweets, and 4.4% from cakes and muffins [19].

Although diversity of nutritious food groups, energy, and macronutrients is likely to be high, some micronutrient requirements may not be met [20]. Women of reproductive age are most likely to experience nutrient deficiencies linked to limited dietary diversity [21]. Reduced household food variety among Māori and Pacific families has been attributed to low income or living in socioeconomically deprived areas [19]. As reported by de Oliveira Otto et al. [22] and others [23–25], high food or food-group counts (greater diversity) may not necessarily be beneficial; obesity measures such as weight, BMI, and waist circumference have been associated with consuming more unhealthy foods (e.g., bakery items, desserts, salty snacks, or refined carbohydrates) versus healthy foods (fruits, vegetables, meat, and dairy).

The contribution of both nutritious and discretionary foods and food groups to dietary and micronutrient diversity remains unknown in the NZ environment, where both food and energy supplies are abundant. Therefore, the aim of this research was to develop and evaluate a DDQ that accurately reflects the food-group diversity, food variety, and micronutrient adequacy of the diets of New Zealand European (NZE), Māori, and Pacific women ages 16 to 45 y.

Methods

Dietary assessment tools

Development of the DDQ

The Guidelines for Measuring Household and Individual Dietary Diversity by the Food and Agriculture Organization [1] and a dietary diversity measurement tool created by the Food and Nutrition Technical Assistance III project [26] were used to guide the development of the DDQ. The questionnaire format was based on a DDQ created and successfully implemented by one of the researchers (R. K.) for a South African population (nutritious foods only, as typically used in low-income countries) [27]. It included a list of generic foods grouped into relevant food groups [1,28], and participants ticked each food item once (yes or no) if they consumed the food over the last 7 d. Three of the authors—two dietitians (R. K., K. L. B.), one with experience in dietary diversity research (R. K.), and a student dietitian researcher (A. J. H.)—worked together to create a similar questionnaire relevant to NZ. We used the NZ Food Composition Tables [29] and latest (2008/2009) National Nutrition Survey results [19] to identify foods commonly consumed by NZE, Māori, and Pacific women. Web searches on Māori and Pacific traditional foods and assistance from cultural advisors provided insight into cultural foods to include in the DDQ. A novel development was to expand the list to include discretionary food groups and items to address the diverse high-income NZ food landscape, where both nutritious and discretionary foods are abundant and excessive food consumption is common. Foods were considered discretionary if they were high in fat, sugar, or sodium, or low in micronutrients, or prepackaged, processed, or sold in takeout food outlets. Food groups suggested in the Guidelines for Measuring Household Dietary Diversity were considered in classifying foods as nutritious or discretionary [1].

A paper copy of the DDQ was piloted with female, ethnically diverse, second- and third-year undergraduate nutrition students (the majority of them ages 18–45 y) to assess its completion instructions and content. Students added foods and comments on the paper copies, which were collated. Directly after completion, the researchers conducted focus-group discussions with the two student groups (15–20 per group) regarding their experience. Notes were taken about completion aspects, each food item on the DDQ, and additions required. In addition, research-team members conducted face-to-face interviews with NZE, Māori, and Pacific women to review the developed DDQ for understanding of questions and instructions for completion, and to ensure appropriateness for these population groups. Results from all the interviews were collated by the student dietitian researcher (A. J. H.), revealing that the questionnaire was quick (timed completion about 10 min) and straightforward (few problem areas recorded) to complete. Additional foods mentioned were added as follows: “artichoke” was added to the “vegetable” food group, “soy milk” to “other milks (e.g. soy, rice, almond milk, etc.),” and “tofu, tempeh” to “legumes and nuts.” The findings highlighted that clarification was needed for foods in different forms—for example, gluten-free cake would be categorized under cakes—and changes were made to the original instructions to accommodate this. Important decisions and assumptions that were made during the DDQ development process are included in Supplementary Table A.1. It was piloted a second time using an online format with postgraduate nutrition and dietetic students (majority female, ages 16–45 y). No other food suggestions were raised from this pilot, nor were there any difficulties in understanding the included foods or the completion instructions.

The final DDQ comprised 237 foods (143 nutritious and 94 discretionary) grouped into 14 food groups: flesh foods (meat, poultry, fish); eggs; dairy products; breads, cereals, and starchy vegetables; legumes and nuts; fruits and juices; vegetables; oils and fats; drinks; alcohol; sauces, spreads, and flavorings; sweet snacks; savory snacks; and takeout and fast food. Both nutritious and discretionary foods were included in most food groups, to avoid bias during completion (Supplementary Table A.2). The DDQ was uploaded to an online survey software system (SurveyMonkey), and a printed option was available if internet access was a problem.

Weighed food records

Weighed food records (WFRs) are considered the gold-standard reference method in dietary assessment [30]. A 4-d WFR was used as the reference dietary assessment method in this study. Four consecutive days, including at least one weekend day, were allocated to provide a range of all days of the week across participants.

Study design and population

The research setting for this evaluation study was a subsample within the larger Women’s EXPLORE (EXamining Predictors Linking Obesity Related Elements) study, a cross-sectional study conducted in Auckland, NZ [31]. The first 135 participants recruited into the EXPLORE study were invited to participate in this substudy, with the aim of obtaining a sample of at least 100, which is the recommended sample size for studies evaluating dietary assessment methods [28,32]. In addition to the DDQ, these participants completed the WFR, which was not part of the EXPLORE study protocol. Inclusion criteria for the EXPLORE study were female gender; age 16 to 45 y; NZE, Māori, or Pacific ethnicity; premenopausal and post-menarche (≥1 year) status; and being non-pregnant, non-lactating, and free of chronic disease. Participants provided written, informed consent. Ethical approval for this research was obtained from the Massey University Human Ethics Committee (Southern A, Application 13/13).

Recruitment and study procedures

Participants were recruited through media articles and advertising. Screening involved a questionnaire for demographic characteristics and health establishing the inclusion criteria [31]. After this, participants visited the Human Nutrition Research Unit at Massey University, Auckland, for data collection. Measurements for this study included weight (bioelectrical impedance; InBody230, Biospace Co. Ltd., Seoul, South Korea) and height (stadiometer), to calculate BMI and assess body composition [33]. All participants watched a DVD on completing the WFR (developed by study dietitians and nutritionists) and received a food-portion guide pamphlet [34], a 4-d diary to record their food intake, and electronic scales (Tanita KD-200).

After their appointment, participants completed the 4-d WFR in real time at home. The online DDQ was completed retrospectively 7 d after their appointment, taking 10 to 15 min. The two dietary assessment methods therefore covered the same period. After completion, the WFRs and paper-based DDQs were returned in person or posted using a prestamped envelope. Reminders were sent via text messages and follow-up phone calls to encourage completion.

Data handling and analysis

Participants were excluded from this study if they did not complete both the DDQ and the WFR. For data analysis, the food groups were disaggregated from 14 to 25 (seven of them to 16 nutritious groups comprising 143 foods, and seven of them to nine discretionary groups comprising 94 foods), to allow discrimination between nutritious and discretionary foods and groups (Supplementary Table A.2). The DDS and FVS were calculated independently from both the DDQ and the WFR (recorded foods scored against the DDQ) to calculate all, nutritious, and discretionary food groups and foods consumed, respectively. The nutritious FVS over the 7-d period was categorized as low (≤30 foods), moderate (31–60 foods), or high (≥61 foods) [27]. In addition, the energy and nutrient composition (protein, fat, carbohydrate, and 13 micronutrients) of the WFRs were analyzed using FoodWorks Professional Edition version 7 [35] and FOODfiles 2010 [36]. The nutrient adequacy ratio (NAR) and mean adequacy ratio (MAR) derived from WFR or 24-h-recall nutrient intake data are commonly used to validate DDQs [30]. The NAR is the ratio of the reported actual intake of a single nutrient against that nutrient's estimated average requirement (EAR), and is used to assess the prevalence of inadequate intakes within groups [37]. The MAR (nutrient adequacy) is the sum of all NARs, divided by the total number of nutrients used. Validation scores (NAR and MAR) were calculated for 13 micronutrients (vitamin A, vitamin C, thiamine, riboflavin, niacin, folate, vitamin B_6, vitamin B_{12}, iron, zinc, calcium, selenium, and iodine) to provide a measure of micronutrient adequacy. These micronutrients were selected based on micronutrients used in previous dietary diversity research [5,13,15,21,38,39], as well as nutrients of concern in NZ women [19]. The 13 calculated NARs were averaged to calculate the MAR. A NAR of 1 represents 100% consumption of the EAR for that micronutrient. NAR values > 1 were truncated to 1 before calculation of the MAR to avoid having micronutrients consumed in adequate or high amounts compensate for those consumed in low amounts. Energy and macronutrients were excluded from MAR calculations to avoid overcompensating for micronutrient intake [5].

Statistical analysis

Statistical analysis was conducted using SPSS for Windows software, version 22.0 (IBM Corp., Armonk, NY, USA). Data were tested for normality using Shapiro–Wilk tests, Kolmogorov–Smirnov tests, and normality plots. Descriptive statistics were used to describe demographic characteristics and DDQ and WFR data. Mean ± SD was used to describe parametric data, median (interquartile range) for non-parametric data, and frequency summary statistics for categorical data. Dietary diversity measures (DDS and FVS) calculated from the DDQ and WFR were correlated using the Spearman ranked correlation coefficients to assess relative validity. Dietary diversity measures from the DDQ were correlated with the MAR from the WFR using Spearman ranked correlation coefficients to assess construct validity. Cross-tabulation of the dietary diversity measures was conducted to investigate how nutritious and discretionary foods and food-group counts related to the MAR. A P value < 0.05 was considered statistically significant.

Results

Of the 135 EXPLORE study participants who were recruited in this substudy, only 101 were included in the data analysis, due to either WFRs or DDQs not being completed or returned. The "snack food" group data from the DDQ were missing for three participants, but their other DDQ data were included in the analysis. The mean age of participants was 32.1 ± 7.4 y. Most women were of NZE ethnicity (82.2%), followed by Māori (10.9%) and Pacific (6.9%). The median BMI was 23.3 (21.1–26.1) kg/m^2. Nearly one-third (32.3%) had a high BMI (≥25 kg/m^2), with 13.1% classified as obese (≥30 kg/m^2).

Dietary diversity and food variety (associations between the DDQ and WFR)

Median DDS and FVS, and correlations, are summarized in Table 1. Correlations ranged from 0.25 to 0.34 for DDS and from 0.22 to 0.39 for FVS. Only 11 participants (10.9%) consumed all 25 food groups, and one participant consumed 13 food groups (the fewest).

Most participants (74.3%) consumed a moderate variety of nutritious foods (31–60) over 7 d. All participants consumed food from two discretionary food groups ("sauces, spreads, and flavorings" and "sweet snacks"), and most (99%) from three nutritious food groups ("vitamin A-rich fruits and vegetables," "oils and fats," and "breads"). The least-consumed food groups were "fish and seafood" (74.3%), "legumes" (68.3%), and "discretionary breads, cereals, and starchy vegetables" (37.6%). Supplementary Table A.3a and A.3b shows the diversity, or lack thereof, of nutritious foods consumed in each food group. For example, although different legumes (seven) and kinds of fish and seafood (nine) were consumed by the participants, many women did not eat legumes (n = 32) or fish and seafood (n = 26) at all.

There was no significant difference in the median FVS between the DDQ and the WFR (adjusted to 7 d) for 15 out of the 25 food groups. For 22 of the food groups, the FVS correlations between the DDQ and the WFR were significant. The exceptions were "discretionary breads, cereals, and starchy vegetables," "discretionary dairy products," and "vitamin A-rich fruits and vegetables." The mean correlation coefficient was 0.36, with 19 food groups ≥ 0.3 and 15 groups > 0.4 (data not shown).

Nutrient intakes and adequacy (WFR)

All participants met the protein EAR, with the NAR (2.31 ± 0.64) exceeding the adequate value of 1 (Table 2). Participants consumed adequate micronutrients, with NARs all greater than 1, except for iodine (NAR, 0.67 ± 0.49), for which 94.1% did not meet the EAR.

Table 1
Comparison of dietary diversity measures between the dietary diversity questionnaire and weighed food records (n = 101)

Score	Maximum	Median (interquartile range) DDQ	Median (interquartile range) WFR	DDQ range	WFR range	r_s*	P
DDS	25	23 (21–23)	18 (17–19)	13–25	12–22	0.33	0.001
Nutritious DDS	16	15 (14–16)	13 (12–14)	8–16	9–16	0.34	0.001
Discretionary DDS	9	7 (7–8)	6 (5–7)	4–9	3–8	0.25	0.012
FVS	237	75 (61–87)	45 (37–52)	17–160	24–67	0.22	0.03
Nutritious FVS	143	49 (41–59)	29 (24–34)	8–107	13–48	0.21	0.03
Discretionary FVS	94	25 (18–32)	16 (12–18)	9–58	3–31	0.39	≤0.001

DDQ, dietary diversity questionnaire (measured over 7 d); DDS, dietary diversity score; FVS, food variety score; WFR, weighed food record (measured over 4 d)
Low FVS: 0–30 food items; medium FVS: 31–60 food items; high FVS: ≥61 food items
*Spearman correlation between dietary diversity scores derived from DDQ and WFR.

Table 2
Average daily nutrient intakes and nutrient adequacy ratios (food records; n = 101)

Nutrient	Food record intake (mean ± SD)	EAR	Participants not meeting EAR, %	NAR (mean ± SD)	NAR range
Energy, kcal	1890.1 ± 417.5	1976*	60.4	0.77 ± 0.18	0.41–1.77
Total protein, g (%TE)	85.6 ± 23.7 (18.1 ± 3.94)	37 (15–25)†,‡	0 (20.8)	2.31 ± 0.64	1.27–5.50
Total fat, g (%TE)	76.1 ± 23.1 (34.5 ± 6.98)	20–35†	46.5	–	–
Carbohydrates, g (%TE)	204 ± 58.6 (41.6 ± 7.32)	45–65†	70.3	–	–
Fiber, g	26.7 ± 16.9	25 ‡,§	58.4	1.07 ± 0.68	0.43–6.21
Thiamine, mg	1.50 ± 0.75	0.9	14.9	1.67 ± 0.83‖	0.69–5.44
Riboflavin, mg	2.13 ± 0.66	0.9	0	2.36 ± 0.73‖	1.10–5.56
Niacin, mg	17.8 ± 6.18	11	8.9	1.62 ± 0.56‖	0.55–3.40
Total folate, μg	409 ± 173	320‡	36.6	1.28 ± 0.54‖	0.46–3.90
Vitamin B_6, mg	2.16 ± 1.06	1	5.9	1.96 ± 0.96‖	0.77–6.29
Vitamin B_{12}, μg	4.46 ± 5.06	2	5.9	2.23 ± 2.53‖	0.55–24.7
Vitamin C, mg	102 ± 57.2	30‡	7.9	3.41 ± 1.91‖	0.38–9.95
Vitamin A, μg RE	945 ± 965	500‡	17.8	1.89 ± 1.93‖	0.45–18.4
Iron, mg	13.2 ± 4.75	8‡	4	1.64 ± 0.59‖	0.81–5.65
Calcium, mg	953 ± 329	840‡	38.4	1.13 ± 0.39‖	0.44–2.85
Selenium, μg	72.4 ± 82.4	60‡	46.5	1.45 ± 1.65‖	0.38–15.6
Iodine, μg	66.7 ± 49.2	100‡	94.1	0.67 ± 0.49‖	0.14–4.18
Zinc, mg	10.7 ± 3.47	6.5‡	4	1.65 ± 0.53‖	0.85–4.77
MAR	–	–	–	1.77 ± 0.58	0.89–5.00
Truncated MAR	–	–	–	0.94 ± 0.04	0.78–1.00

%TE, percentage of total energy intake; AI, adequate intake; EAR, estimated average requirement; NAR, nutrient adequacy ratio; MAR, mean adequacy ratio; RDI, recommended dietary intake
*Based on average EAR for women ages 19–30 and 31–50, using mean height of 1.6 m and physical activity factor of 1.5 [37].
†Acceptable macronutrient distribution range used where EAR, RDI, and AI are not available or in addition to EAR [37].
‡For participant (n = 1) age 18 y, the EARs specific to her age used were as follows: protein, 35 g; fiber, 22 g; total folate, 330 μg; vitamin B_6, 1 mg; vitamin C, 28 mg; vitamin A, 485 μg; calcium, 1050 mg; selenium, 50 μg; iodine, 95 μg; zinc, 6 mg.
§AI used where EAR or RDI is not available.
‖Included in MAR calculation.

Vitamin B_{12} had the greatest range of nutrient intake, with NAR values ranging from 0.55 to 24.7. The MAR (average of truncated NARs) was 0.94 ± 0.04, suggesting adequate nutrient intake.

Relationships between DDSs and adequacy ratios

The relationship between the nutritious DDS and MAR was significantly, but weakly, correlated (r_s = 0.199, $P < 0.05$), as were those between DDS and both vitamin B_{12} NAR (r_s = 0.262, $P < 0.01$) and selenium NAR (r_s = 0.248, $P < 0.05$; data not shown).

We further investigated the relationships between increasing nutritious DDS and the mean truncated NARs (Fig. 1), focusing on several important nutrients for women. Selenium and iodine intake were lowest when only eight nutritious food groups were used. Iodine intake was highest when nine nutritious food groups were used, never reaching a NAR of 1.

To show how nutrient intake relates to the number of foods and food groups consumed, we cross-tabulated DDS and FVS with the MAR (Table 3). Most participants consumed 41 to 60 foods from 15 or 16 nutritious food groups over 7 d, resulting in an average MAR of 0.94 to 0.95 (as shown with italics; Table 3). A weak trend indicated that with increasing discretionary FVS and DDS, the diet has a lower MAR.

Discussion

In this study, we designed, developed, and evaluated a dietary diversity questionnaire for use in NZ women. The DDQ was specifically designed to include both nutritious and discretionary foods that are generic to the food supply, but also culturally specific foods typical of the NZ food environment. This is one of only a few dietary diversity studies conducted in a high-income setting to explore both nutritious and discretionary dietary diversity. The DDQ was found to be a low-burden tool able to assess diet quality, distinguish nutritious versus discretionary food choices over 1 wk, and provide insight into habitual food choices.

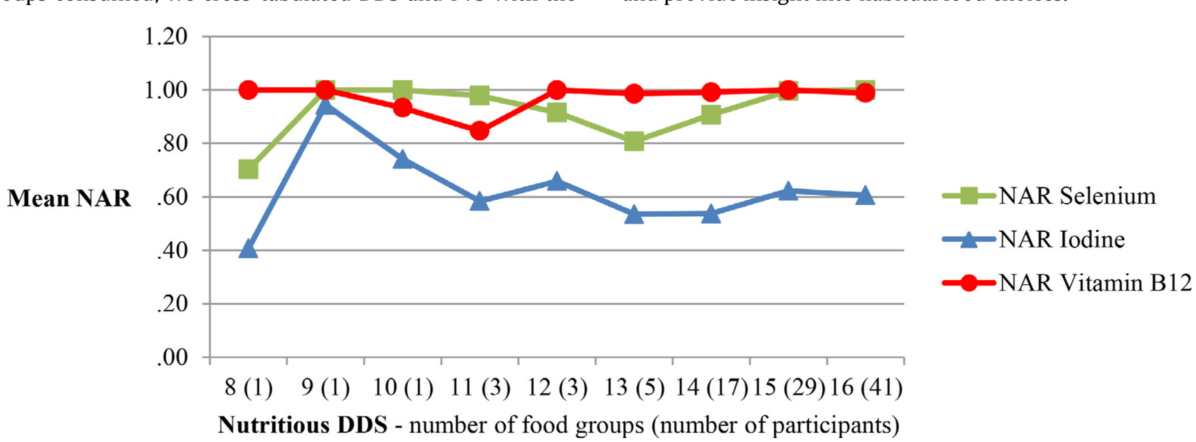

Fig. 1. Mean truncated NARs of selenium, iodine, and vitamin B_{12} at different DDSs (n = 101). DDS, dietary diversity score; NAR, nutrient adequacy ratio.

Table 3
Cross-tabulation of mean adequacy ratios at different nutritious and discretionary dietary diversity and food-variety scores (n = 101)

Nutritious DDS	Nutritious FVS					
	0–20	21–40	41–60	61–80	81–100	101–120
8	0.90 (n = 1)					
9	0.98 (n = 1)					
10		0.92 (n = 1)				
11		0.90 (n = 2)	0.98 (n = 1)			
12		0.92 (n = 1)	0.94 (n = 2)			
13		0.94 (n = 4)	0.95 (n = 1)			
14		0.94 (n = 7)	0.92 (n = 8)	0.91 (n = 1)		0.97 (n = 1)
15		0.94 (n = 4)	***0.95 (n = 22)***	0.89 (n = 3)		
16		0.95 (n = 4)	***0.94 (n = 22)***	***0.95 (n = 12)***	0.96 (n = 3)	
Discretionary DDS	Discretionary FVS					
	0–20	21–40	41–60			
4	0.99 (n = 2)					
5	0.92 (n = 5)					
6	***0.94 (n = 13)***	0.98 (n = 1)				
7	***0.96 (n = 11)***	***0.93 (n = 24)***				
8	0.96 (n = 4)	***0.95 (n = 24)***	0.97 (n = 1)			
9		***0.94 (n = 10)***	***0.89 (n = 6)***			

DDS, dietary diversity score; FVS, food-variety score

Dietary diversity

The moderate number of nutritious foods (FVS; 49, 41–59) consumed over 7 d suggests greater food variety compared to studies in other countries. Studies in low-income countries have reported low food variety—for example, in Mali a mean FVS over 2 to 3 d of 20.5 [13], and in South Africa a FVS over 7 d in women of low socioeconomic status averaging only three foods [15]. The DDS from nutritious food groups in the present study—15 (14–16)—was high compared to the Mali study, which reported a mean DDS of 5.8. Similarly, the South African women's mean DDS over 7 d was 2.8. However, in our study, the nutritious food groups were disaggregated to 16 groups, compared to the eight or nine food groups used in these other studies. One study in Iranian adolescents reported a mean DDS of only 6.3, despite including 23 nutritious food groups. Comparative DDS or FVS data are not often available for high-income countries. Diet quality indices are often used instead, revealing poor food variety as a common shortfall of the Western diet, affecting poor health outcomes such as weight gain, high BMI, abdominal obesity, risk of cardiovascular disease, some cancers, and mortality [40,41].

To account for intake of foods in a high-income setting, both nutritious and discretionary dietary diversity were investigated. The median total DDS and FVS (nutritious and discretionary) consumed over 7 d were 23 (21–23) and 75 (61–87), respectively. In contrast, a dietary diversity study conducted in women from three different areas in Vietnam that included discretionary food groups [42] had mean DDSs of 8, 8, and 10, and FVSs of 16, 17, and 19 over 7 d. Other dietary diversity studies in low-income countries [5,13,15,39,43] have not included discretionary foods and food groups in their diversity indicators. In the present study, the median discretionary FVS was 25 from a possible 94 discretionary foods, in addition to a median nutritious FVS of 49 from a possible 143 nutritious foods. This means that approximately one-third of the foods consumed were discretionary in nature, reflecting the NZ environment with high food availability and accessibility of both healthy and unhealthy foods [20].

Nutritional diet quality

Ideal NAR and MAR values (1 or 100%) indicate adequacy [1,13]. Using this approach, a number of studies in low-income countries have found significant associations between FVS, DDS, and MARs, indicating that dietary diversity measures provide an alternative method to assess nutritional adequacy of diets [1,5,12,13,15,42]. The MAR of 0.94 in our group of women represented near-adequate mean micronutrient intakes. This is high compared to other studies in low-income countries reporting lower MARs: 0.77 in South Africa, 0.50 in South Africa, and 0.50 in Mali [5,15,44], which suggest that those participants were not meeting nutrient recommendations. A high dietary MAR may, however, mask the level of diversity of nutritious foods consumed. Women with high dietary variety may consume both nutritious and discretionary foods, but when the ratio of intake is skewed, micronutrient intake might not be optimal. Similarly, other studies have reported that higher food counts are often associated with consuming excessive unhealthy (discretionary) foods such as sweets and sugar-sweetened beverages [22,25].

In this study there was only a weak association between MARs at different levels of DDS and FVS, with MAR increasing slightly as nutritious DDS and FVS increased. Cross-tabulation showed that when only 0 to 20 foods were consumed from only eight food groups, the MAR was 0.90, but when 81 to 100 foods were consumed from 16 groups it improved to 0.96. The MAR decreased slightly as discretionary DDS and FVS increased; participants consuming 41 to 60 discretionary foods from nine food groups had a MAR of 0.89, compared to those eating only 0 to 20 discretionary foods from four food groups, who had a MAR of 0.99. This is expected, as discretionary foods are generally poor in micronutrients due to their content of refined sugar and fat [45], and thus do not contribute to diet quality. Conversely, when MAR was cross-tabulated against DDS and FVS in a South African study, a much clearer trend showed an increasing MAR from 0.28 to 0.84 with increasing FVS and DDS (going from two foods from one group to six foods from five groups) [15].

Evaluation of the DDQ compared to the WFR

The developed DDQ was evaluated first by correlating sets of dietary diversity measures (DDS and FVS) calculated independently from the DDQ and the WFR. Both sets of dietary diversity measures were significantly correlated between the DDQ and the WFR. For 15 of the 25 food groups, the food-group-specific FVSs were similar between the two methods. The performance of the

DDQ was shown to have reasonable relative validity versus WFR-generated dietary diversity measures. The DDQ could therefore be used as a proxy when the 4-d WFR is inappropriate to use, or when quick assessment of diet quality is indicated [30]. The second evaluation technique involved correlating the dietary diversity measures with nutrient validation scores. Significant correlations were found between the nutritious DDS and the MAR ($P < 0.05$), suggesting that the likelihood of participants consuming the EAR for the 13 micronutrients we investigated increased as the number of nutritious food groups consumed increased. However, this correlation was weak ($r_s = 0.199$, $P < 0.05$). Although the count of nutritious food groups consumed is always important to consider, it may be less useful in its ability to reflect nutrient adequacy in a high-income setting. Larger quantities of food are generally consumed from a more varied food supply that includes both nutritious and discretionary foods [40]. Subsequently, most food groups are consumed, reflecting high DDSs and MARs.

However, there were no significant correlations between nutritious FVS (foods) and NAR or MAR, showing that the likelihood of meeting the EAR did not increase in line with an increase in the total number of foods consumed from each group. We hypothesize that this may be due to the large number of foods and food groups consumed, reaching the EAR easily and therefore not showing an impact of food variety. Similar to our findings, a study in Mali found that DDS was a stronger determinant of MAR than FVS [13]. However, another study (also in Mali) found that FVS was a stronger determinant of MAR than DDS [44] when the contribution of food groups to MAR was further explored. Three food groups explained the variation in MAR, and these were the sources of nutrients that were most limiting to MAR (vitamins A and C and calcium). The positive relationship was due to various reasons; for calcium, all items in the milk group had similar nutrient contributions, and therefore increasing the amount consumed rather than food-group variety as such was responsible for the positive relationship. However, for green vegetables, there was no relationship between number and amounts, indicating that the effects on MAR were mainly due to variation [44]. It has been postulated that the variety within a group is more important than the number of servings consumed [6].

In this study, nutritious food intake was not as high as expected in a high-income setting. It was only moderate (median, 49 foods), and was offset by women adding more discretionary foods (median, 25 foods) to their diet, with both contributing to nutrient intake. This is confirmed by studies reporting that greater dietary diversity may not necessarily indicate more nutritious or healthy food choices; it could equally indicate excessive discretionary food choices [22,25]. The balance between nutritious (more) and discretionary (fewer) foods and groups is an important consideration for a high-quality diet. Ruel [12] concluded that food-group diversity should be the preference method for measurement purposes, thanks to its simplicity. However, in developing nutritional education strategies, it is important to promote food variety both within and between food groups [16]. Therefore, it is considered more important first to consume foods from as many nutritious food groups as possible. Second, it is important to include a well-chosen variety of foods within each food group (e.g., if having three portions of dairy, include milk, cheese, and yogurt as three different foods) rather than more portions of the same foods (e.g., three portions of cheese, but no milk or yogurt), to improve the likelihood of consuming adequate nutrients. The results also support the importance of consuming fewer discretionary foods, as MAR decreased slightly when discretionary DDS and FVS increased.

The strengths of this study include the contribution to the methodology available for dietary diversity assessment in high-income countries. The developed DDQ includes both nutritious and discretionary foods and food groups, an important consideration in a high-income setting. Previous dietary diversity validation studies have mainly used techniques correlating dietary diversity measures with validation scores (e.g., MARs) that reflect nutrient intake [5,13,15], but they have not used another set of comparable dietary diversity measures from the reference method. The present study used both validation scores to assess the ability of the DDQ to estimate nutrient adequacy and a set of dietary diversity scores calculated directly from the WFRs to evaluate the DDQ's ability to measure dietary diversity. In addition, both nutritious and discretionary food groups were included in the analysis, to mirror the diversity component that defines a quality diet. Other strengths of this evaluation study are the large sample size, the ethnically diverse sample, and the generic design of the DDQ (a range of food items typically consumed in high-income countries, which are generic rather than brand specific). This makes the DDQ applicable for use in other high-income settings, requiring minor adaptations including food terminology, available foods (e.g., fruits and vegetables), or culturally specific food items. However, if any dietary assessment tool requires an update of a food list, then it should be reevaluated for use in the applicable population [46].

A limitation of the study is that participant food records may not reflect their actual intakes. Participants often change their usual behavior when recording WFRs, mainly due to the inherent measurement error and associated completion burden of self-reported dietary assessment methods [47,48]. Another limitation is the timing of the WFR administration. In validation studies, it is suggested that the test method be administered before the reference method, to avoid increasing participants' awareness of their food intake and subsequent alteration of the way the test method is completed [28]. In this study the DDQ was completed after the food records, hence the accuracy of the DDQ may have been improved through completion of food records. However, test and reference methods should cover the same period, which required these two methods to be conducted in this order. The number of days of assessment varied between the DDQ and the food record, which meant that direct comparisons between scores from the two assessment methods could be performed only with adjusted data. We were unable to undertake sensitivity and specificity analysis to determine the ability of DDS and FVS cutoffs to accurately reflect diet quality (MAR), due to most participants consuming adequate micronutrients, meaning that regardless of the number of food groups consumed, nutrient intakes were adequate. Finally, the results from this cross-sectional study are only relevant for young women and cannot be generalized to the wider population.

Conclusions

The DDQ showed reasonable relative validity in its ability to measure dietary diversity among NZ women, as the scores calculated independently from the DDQ and the WFR were significantly correlated. The nutritious DDS was significantly correlated with the MAR, indicating that the DDQ has reasonable ability to reflect diet quality in the high-income NZ setting. The DDQ data provided insight into the high variety of discretionary foods consumed—with increasing discretionary FVS and DDS, the diet had a lower MAR. With high overweight and obesity rates in NZ, the DDQ could be used as an easy, quick, low-burden method to determine diet quality and nutritional adequacy. It can identify key nutrients (via food-group analysis: DDS) as well as key foods (via food-item analysis: FVS) to address optimizing the diet by simply reviewing the completed DDQ. For example, in assessing the dairy group, high discretionary intake can easily be identified, for example, sweetened yogurt drinks and processed cheese. From viewing the food lists, replacement suggestions would be easy in a discussion with the client, such as low-fat Greek yogurt and Edam cheese. The developed DDQ is a valuable tool for assessing the types and ratios of nutritious and discretionary food choices. Further validation of the DDQ is needed in different high-income settings across similar intake periods, as well as independently among ethnicities and different population groups.

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Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.nut.2021.111468.

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