Development and validation of a dietary diversity questionnaire for New Zealand women

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Abstract

Background: Dietary guidelines recommend eating a variety of food and food groups. Dietary diversity is the count of individual food items and/or food groups consumed during a defined period of time. In developing countries dietary diversity reflects food accessibility, household food security, socioeconomic status and nutritional adequacy of individual diets.

Aim: To develop and validate a dietary diversity questionnaire (DDQ) that accurately reflects the nutritional adequacy and optimisation of New Zealand women's diets.

Method: A DDQ was developed based on intake of New Zealand women. Women aged 16-45 years (n=101) completed the DDQ based on their food intake over a seven period. A four-day weighed food record (FR) was also completed as a reference dietary assessment method. Measures of dietary diversity (dietary diversity scores (DDS) and food variety scores (FVS)) were calculated from both the DDQ and FR and compared using correlation coefficients and Wilcoxon Signed-Rank Test. Nutrient adequacy ratios (NAR) and nutrient optimisation ratios (NOR) were calculated from the FR and assessed against DDS and FVS using correlation coefficients. Cross-tabulation of DDS and FVS was conducted to investigate their ability to determine adequate and optimal nutrient intake.

Results: The median (25, 75 percentile) DDS (food groups) and FVS (food items) per week was 23 (21, 23) (maximum 25) and 75 (61, 87) (maximum 237), respectively. The intake of nutritious food items was classified as medium (31 – 60 food items), with a nutritious FVS of 49. Correlations were present between all dietary diversity measures calculated from the DDQ and FR. The mean ± SD of NAR was 0.94 ± 0.04, suggesting near adequate nutrient intakes. The mean ± SD of NOR was 0.84± 0.16, suggesting high but not optimal nutrient intakes. Specifically, intakes were not optimal for iron, iodine and zinc. The intake of nutritious food groups was significantly correlated to the mean adequacy and optimisation ratios, r=.199 (P=0.046) and r=.258 (P=0.009), respectively.

Conclusions: The DDQ is a relatively valid method for assessing dietary intake in New Zealand women. Further research is required to investigate associations between dietary diversity and health outcomes.

Key words: Dietary diversity, nutrient adequacy, validation

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1. Introduction

1.1 Background and Justification for Research

Including a variety of foods is often encouraged as part of a healthy diet. It is thought to increase the variety of nutrients consumed and therefore improve health outcomes (FAO, 2011; Jansen *et al.*, 2004; Kant, Schatzkin, Harris, Ziegler, & Block, 1993; Michels & Wolk, 2002; Steyn, Nel, Nantel, Kennedy, & Labadarios, 2006). In New Zealand, it is recommended that adults include a variety of foods from each of the major food groups (fruit and vegetables; breads and cereals; milk and milk products; and lean meat, poultry, seafood, eggs or alternatives) in their diets daily (Ministry of Health, 2003a). There is not one single food that provides all the necessary nutrients for health, therefore the greater the range of foods eaten, the greater the probability that nutritional needs will be met (Labadarios, Steyn, & Nel, 2011). While the intake of individual foods and nutrient is important, so is the overall variety or diversity of diets (dietary diversity).

Dietary diversity has been defined as the count of food items and/or food groups consumed over a certain time period (Ruel, 2003). This measure is able to reflect the variety of food accessible to an individual or household, and represent nutrient adequacy of individual diets (FAO, 2011).

Nutrition assessment is the evaluation of nutrition status through investigation of nutritional history and nutrition-related health indicators, such as dietary, medical and social history, physical examination, anthropometric measurements and biochemical data (Mahan, Escott-Stump, & Raymond, 2012). Nutrition assessment is necessary for determining the nature and degree of nutrition status.

There are many different methods and processes involved in a nutritional assessment. Dietary assessment is a key component of nutrition assessment. It is the collection of information on food consumption, such as quantity of food, frequency of eating and types and quality of food consumed (Biro, Hulshof, Ovesen, & Cruz, 2002). Dietary assessment is conducted in a range of settings, including small-scale research, national surveys, epidemiological studies, and provision of individualised dietary advice (Black, 2001). Each of these settings has different requirements in regards to the type of the data gathered via dietary assessment methods. There are a range of different dietary assessment methods available, with the choice of method dependent on the purpose of the dietary data collection and the setting in which the assessment is carried out. In studies focusing on intakes of population groups, there is more of

a focus on obtaining an overview of the populations' dietary habits. However, in research investigating individuals, dietary assessment may require more intricate detail about dietary intake. Regardless of the setting or type of dietary assessment method used, quality dietary data is always desired.

It may be a common belief that the assessment of usual food and nutrient intake is easy and straightforward. However, collection of dietary data that is reliable and accurate is a difficult task. This is due to many reasons, including but not limited to day-to-day variability in food intake, misreporting of intake, variation in daily intake of meals and snacks, presence of confounders (such as under-reporting intake, seasonal variations in food supply, faulty dietary scales), and limitations associated with use of nutrient composition tables (Biro *et al.*, 2002; Black, 2001; Mahan *et al.*, 2012; Roman-Vinas *et al.*, 2009).

Dietary assessment methods can be classified into different groups depending on the type of data gathered (quantitative or qualitative), time frame being assessed (retrospective or prospective), or length of time being assessed (short or long term). Dietary assessment methods are often selected based on the period of food intake needing to be assessed. Short term methods include the 24-hour recall, where participants' recall their food intake from the previous 24 hours, and the dietary record, where food and fluid intake is recorded over a number of days (Biro *et al.*, 2002). Long-term methods include dietary history or food frequency questionnaires, and these assess usual intake over previous months or years.

Each dietary assessment method has its strengths and weaknesses. There is not one current dietary assessment method that can perfectly assess dietary intake. Some of the weaknesses of dietary assessment methods include the need for a skilled interviewer; interviewer bias; time taken to complete; may not reflect usual intake, e.g. a single 24-hour recall; high literacy skills or education level required of participants; under- or over-reporting of food intake; and there may be high participant burden, e.g. completing a weighed food record (Biro *et al.*, 2002; Black, 2001; Gibson, 2005; Mahan *et al.*, 2012). Dietary assessment can also be expensive and may require technical skill in order gather the data as well as analyse (FAO, 2011). A new dietary assessment method which minimises these downfalls would be beneficial to future nutrition research.

Measurement of dietary diversity is a technique that has been developed and used to assess diets of individuals and household access to a variety of foods, particularly in low socio-economic communities (Ruel, 2003). Assessment of dietary diversity through a 'yes/no' tick list

offers a potentially useful method of dietary assessment because it requires only a short amount of time, it can be self-directed and high literacy skills and knowledge on portion size is not required. Additionally, participant's food patterns are not altered by completion through measurement of dietary diversity as occurs with food records, and it is inexpensive to execute as skilled interviewers are not required (FAO, 2011).

A diet that is nutritionally adequate means that it meets energy and micronutrient recommendations, and hence is a quality diet (Ruel, 2003). Dietary diversity as a measure of dietary intake has been able to reflect both nutrient adequacy and diet quality in individuals (FAO, 2011; Ruel, 2003). There are many other indicators of dietary quality (Ocke, 2013). An example of another dietary quality index is the Healthy Eating Index. This is a score system where scoring is proportionate to the dietary guidelines being met by the diet. Fruits, vegetables, legumes and grains are worth less points, and energy from solid fats, alcohol and added sugars are worth more points (Guenther, Reedy, & Krebs-Smith, 2008). However, this scoring method only assesses nutrient adequacy and not the variety of the diet, which is the focus of this research study.

Lack of dietary diversity is a serious problem in developing countries, and historically much of the research on dietary diversity is based on populations in these countries, rather than developed countries. Research in developing countries found that changing from a repetitive diet to a diet with a variety of food lead to improved nutrient and energy intake (Ruel, 2003). Diets high in diversity have also been associated with food security and better health outcomes (Hoddinott & Yohannes, 2002; Jansen *et al.*, 2004; Michels & Wolk, 2002).

Minimal investigation of dietary diversity in developed countries has been conducted, where there is high food accessibility and availability of many food types, and excessive intake of non-nutritive foods occurs. Although increased dietary diversity has been associated with better quality diets and improved health (Jansen *et al.*, 2004), at the other end of the spectrum, there may be a link between increased dietary variety and obesity. For example, a recent study on Sri Lankan men found that adults who were obese or had abdominal obesity had significantly more variety in their diets compared to those who were not obese (Jayawardena *et al.*, 2013). Despite increasing levels of overweight and obesity in New Zealand (Ministry of Health and Otago of University 2011), micronutrient deficiencies remain a problem, particularly in women, and this may be linked to limited dietary diversity (Arimond *et al.*, 2010). Dietary diversity is also linked with socioeconomic status and household food security (Hatloy, Torheim, &

Oshaug, 1998; Hoddinott & Yohannes, 2002), and this may also be evident within New Zealand.

Measurement of dietary diversity with actual dietary diversity questionnaires (DDQ)s is limited. A specifically designed DDQ has been used in South Africa (Matla, 2008), however, in most other instances dietary assessment methods have been used to measure and calculate dietary diversity from, including a quantified food frequency questionnaire (Oldewage-Theron & Kruger, 2011), weighed food records (Hatloy *et al.*, 1998), 24-hour recall (Foote, Murphy, Wilkens, Basiotis, & Carlson, 2004; Steyn *et al.*, 2006), and large-scale surveys (Arimond *et al.*, 2010). Food records can provide evidence of dietary diversity, but they give an extensive number of food codes (Drewnowski, Henderson, Driscoll, & Rolls, 1997) which may be difficult and time-consuming to categorise into groups. The development of a DDQ with a more simplified list of foods and food groups will be more manageable than food records which take time to categorise. A DDQ will also have much lower participant burden because the process of completing the DDQ only requires completion of a tick list, whereas weighed food records take a lot of motivation and commitment to complete.

Dietary diversity measures have been developed to evaluate dietary diversity (Ruel, 2003). Two commonly used scores are dietary diversity score (DDS), which reflects the number of food groups eaten, and food variety score (FVS), representative of the number of food items eaten (Hatloy *et al.*, 1998). The DDS and FVS have been shown to reflect nutrient adequacy of the diet through use of validation measures which consider whether recommended dietary intakes of nutrients are met (Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011; Steyn *et al.*, 2006).

The setting in which this research will be carried out is within the Women's EXPLORE (EXamining Predictors Linking Obesity Related Elements) study at Massey University, Auckland. This cross-sectional study is investigating how different body weight and body fat profiles are linked to chronic disease risk in women. The participants in this study are women are 16-45 years of age, and are Māori, Pacific and New Zealand European. A subsample of women from this study will be used to validate the developed DDQ. Participants will also complete a four-day weighed food record to validate the dietary diversity measures obtained from the DDQ. Once validated, the DDQ will provide a simple, accurate, inexpensive and user-friendly dietary assessment method that can be used in the New Zealand context. It will also contribute to research on dietary diversity and diet quality from a different perspective, namely a developed country where there is a vast array of readily available and energy-dense foods consumed.

1.2 Aims and Objectives

Aim

The aim of this research is to develop and validate a DDQ that is suitable for use in New Zealand women aged 16-45 years with Māori, Pacific or New Zealand European backgrounds that can accurately reflect the nutritional adequacy and optimisation of their diets.

Objectives

- To develop a DDQ appropriate for use in the in the New Zealand context.
- To explore the dietary diversity of a subsample of women aged 16-45 years living in New Zealand.
- To validate the dietary diversity measures obtained from the DDQ in s subsample of women aged 16-45 years living in New Zealand.

1.3 Structure of the Thesis

There are six parts to this study, which make up the six chapters of this thesis. Chapter one introduces the research and highlights it's importance. Following this, chapter two consists of the review of literature, which was conducted on DDQ development and validation, and includes sections on dietary assessment, dietary diversity, development of DDQs and validation techniques for dietary assessment methods and specifically for dietary diversity measures. The methods and materials of the study are then explained in chapter three. Chapter four contains the results of this study, and chapter five is a discussion of the results. Lastly, chapter six provides study conclusions and recommendations for future dietary diversity research.

1.4 Researcher's Contribution to Study

Table 1.1 – Contribution of researcher's to study

Researchers	Contributions
AJ Hepburn – Student	Main researcher, developed DDQ, standard operating procedures (SOPs) for DDQ and food record use, recruited participants, data entry and analysis, statistical analysis, interpretation and discussion of results, author of thesis
Rozanne Kruger – Supervisor	Main academic supervisor, primary investigator of Women's EXPLORE Study, application for ethics, development of DDQ, study design, assistance with data entry, analysis, and interpretation of results, reviewed thesis
Kathryn Beck – Supervisor	Academic supervisor, development of DDQ, study design, assistance with data entry, analysis, and interpretation of results, reviewed thesis
Zara Houston	Recruited and screened participants, data entry
Sarah Philipsen	Recruited and screened participants, data entry
Wendy O'Brien	Recruited and screened participants
Shakeela Jayasinghe	Recruited and screened participants
Chelsea Symons	Data entry and cleaning

2. Literature Review

2.1 Dietary Diversity

2.1.1 Introducing dietary diversity

Dietary diversity has been defined as "the number of different foods or food groups consumed over a given reference period" (Ruel, 2003, p. 3912S). It is a qualitative measure that reflects the variety of food items and food groups accessible to and consumed by households or individuals. The two most common dietary diversity measures are household dietary diversity score (HDDS) and individual dietary diversity score (IDDS). Household dietary diversity measures are associated with energy availability and hence may be able to reflect household food security and socioeconomic status (Hoddinott & Yohannes, 2002; Ruel, 2002). Dietary diversity measures on an individual level have been used to reflect nutrient adequacy and diet quality (FAO, 2011). Nutrient adequacy is when the body's requirements for energy and essential nutrients are met through the diet (Ruel, 2003). Dietary diversity is operationalised through a range of dietary assessment methods, and is measured by summing the number of food items and/or food groups consumed over a specified time period.

2.1.2 Meeting nutritional requirements with dietary diversity

The definition of diet quality depends on the attributes chosen by an investigator (Gibson, 2005). There are three categories of attributes: those based on food items or food groups, those based on nutrients, and those based on a combination of foods and nutrients (Kant, 1996). In terms of dietary diversity, diet quality is another term used to describe nutrient adequacy. Dietary recommendations and guidelines are in place to promote nutrient adequacy. Commonly, these guidelines include a recommendation to encourage dietary variety. The term dietary variety is commonly used and is considered to be synonymous with the term dietary diversity. "Variety" refers to the state of being diverse and the absence of monotony (Oxford University Press, 2010). In New Zealand, it is recommended that adults "eat well by including a variety of nutritious foods from each of the four major food groups each day", namely fruit and vegetables; breads and cereals; milk and milk products; and lean meat, poultry, seafood, eggs and alternatives (Ministry of Health, 2003a, p. 4). There is not one single food or food group that provides all the necessary nutrients for health (except for breast milk in the first six months of life), therefore the greater the variety of foods and food groups eaten, the greater the probability that nutritional needs will be met (Labadarios *et al.*, 2011). Choosing two servings of the same food may provide fewer nutrients compared to choosing two servings from two different types of food groups (Foote *et al.*, 2004), for instance two

apples compared to one apple and one banana. In addition to variety of food item consumption, by increasing the diversity of food groups consumed, a greater range of nutrients can be consumed. For example, fruit and vegetables provide substantially more vitamin A, vitamin C and carbohydrates, than meat, fish and poultry which provide protein, vitamin B12 and iron in greater amounts (Ministry of Health, 2003a). See table 2.1 for New Zealand recommended intakes from the food groups and nutrients provided by each group.

Table 2.1 - New Zealand daily food group recommendations for adults and the nutrients they provide

Food Group	**Vegetables and Fruits**	**Breads and Cereals**	**Milk and milk products**	**Lean meat, poultry, chicken, seafood, eggs, nuts, seeds and legumes**
Number of servings per day	At least five servings; 3 servings of vegetables and two servings fruit	At least six servings	At least two servings	At least one serving per day
Nutrients provided	Carbohydrates, dietary fibre, vitamin A, vitamin C, folate, magnesium, potassium	Protein, carbohydrates, dietary fibre, all B vitamins (except vitamin B12), vitamin E, magnesium, calcium, iron, zinc, selenium	Protein, fats, vitamin A, riboflavin, vitamin B12, calcium, phosphorous, zinc, iodine	Protein, fats, carbohydrates (mainly from legumes), vitamin B12, thiamine, niacin, iron, zinc, magnesium, copper, potassium, phosphorous, selenium

Source: (Ministry of Health, 2003a)

Research in developing countries has found that changing from a monotonous diet to a diet with a variety of food leads to improved diet quality (Oldewage-Theron & Kruger, 2009; Ruel, 2003). Through higher levels of dietary diversity and subsequent increased intake of nutrients, health outcomes can be improved (Jansen *et al.*, 2004; Kant *et al.*, 1993; Michels & Wolk, 2002). Furthermore, consuming a wide variety of food in moderate amounts not only reduces risk of nutrient deficiencies, but also nutrient toxicities (Hunt, 1996). Therefore, dietary diversity is a key component of nutritionally adequate diets.

2.1.3 Measurement of dietary diversity

A review conducted by Ruel (2003) enlightens us to how dietary diversity has previously been conceptualised, used and validated. A range of dietary diversity measures have been used previously by researchers. This is due to the different classification systems of food items and food groups in different countries, and the numbers of food items and food groups and the length of reference period included in dietary diversity measurement. These differences aside,

measurement of dietary diversity usually involves the simple process of counting up the number of nutritious food items and/or food groups consumed over a stated time period, without consideration of the number of servings (Hatloy *et al.*, 1998; Ogle, Hung, & Tuyet, 2001; Oldewage-Theron & Kruger, 2011; Steyn *et al.*, 2006). Some dietary diversity measures are more complex, for they example they have included the numbers of servings (Kant *et al.*, 1993), but the most popular measurement approaches tend to be food items or food group counts due to their simplicity (Ruel, 2003). Studies may measure only either number of food groups, or the number of food items, or they may measure both. One dietary diversity measure which is a straightforward count of food groups is the dietary diversity score (DDS), see figure 2.1. This approach allocates points to the different food groups consumed. One point is given if food from a food group is consumed, and depending on the number of food groups available, this would be the maximum score (for example if there were five food groups, then five would be the maximum score) (Kant *et al.*, 1993). Another dietary diversity measure is the food variety score (FVS), which is the count of individual food items consumed (Hatloy *et al.*, 1998) (see figure 2.1). Research in South Africa has led to the creation of a classification system for the FVS. A diet with a FVS of 0 – 30 is classified as having low variety, 31- 60 is medium variety, and 61 and higher is high variety (Matla, 2008).

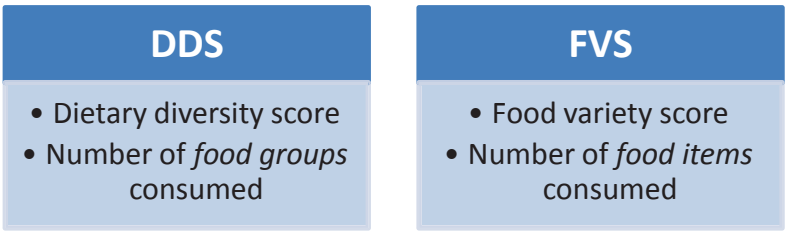


Figure 2.1 – Measures of dietary diversity

The main role of dietary diversity measures is to assess dietary diversity, but they are also used as indicators of overall diet quality. For example, Steyn *et al.* (2006) investigated effectiveness of food variety score (FVS) and dietary diversity score (DDS) as indicators of nutrient adequacy in South African children's diets. They found that FVS and DDS were able to be used as indicators of micronutrient adequacy. Similarly, positive correlations between dietary diversity and micronutrient intake have been found in other studies (Foote *et al.*, 2004; Hatloy *et al.*, 1998; Ogle *et al.*, 2001). Alas, there is currently no international consensus on what food items and food groups should be included in dietary diversity scores in relation to different age groups, cultures and settings.

In addition to this there is absence of consensus and consistency on how to actually measure dietary diversity and how to validate indicators of dietary diversity due to the range of

techniques used in different studies (Ruel, 2003). More recently, in attempt to standardise dietary diversity assessment, the Food and Agriculture Organisation (FAO) of the United Nations created guidelines for measuring household and individual dietary diversity (FAO, 2011). These guidelines also include suggestions on how to measure and analyse dietary diversity data. One key measure they discuss is the DDS. They claim that DDSs are able to assess the probability of micronutrient adequacy of a diet, and hence reflect the nutritional quality of diets (FAO, 2011). Continuing use of these scores may provide consistency in dietary diversity research.

The length of time dietary diversity is assessed usually ranges from one to three days, but reference periods of seven days to 15 days have been used (Drewnowski *et al.*, 1997; Falciglia, Horner, Liang, Couch, & Levin, 2009). The optimal recall period for dietary diversity assessment depends on the extent of diet variability, the recall error, and whether the dietary diversity indicator being used at a population or individual level (Ruel, 2003). If there is greater variability in the diet, it may potentially take more time to cover the diversity of the diet, compared to a monotonous diet which is made up of only a few food items. In order to minimise participant memory lapse, the reference time period needs to be reduced (Smith, Jobe, & Mingay, 1991). A two week period may be better than a one- or three-day period for assessment of dietary diversity, however, in order to avoid and minimise memory error a period of seven days may be the most appropriate reference period (Ruel, 2003). Assessing dietary diversity at a population level may also require a longer reference period compared to the individual level to in order to cover all of the populations dietary variety patterns (Ruel, 2003).

Dietary data collection was intensive in a West African-based study, where interviewers stayed in respondents households for nine hours a day due to participants' low literacy levels (Hatloy *et al.*, 1998). However, single 24-hour recalls have been shown to accurately assess dietary diversity in poverty-stricken communities (Steyn *et al.*, 2006). It may be different in developed countries as it has been found that the count of food items consumed rises rapidly over three days, hence dietary assessment of one day only may significantly underestimate true dietary diversity (Drewnowski *et al.*, 1997).

2.1.4 Previous research on dietary diversity

Poor dietary variety exists in deprived populations living in developing countries where diets consist predominantly of starchy staples, and minimal fruits, vegetables and animal products are consumed (Ruel, 2003). Therefore much of the research on dietary diversity has been

based on populations in these countries, such as Africa (Fujita, Lo, & Baranski, 2012; Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011; Steyn *et al.*, 2006; Torheim *et al.*, 2003), Iran (Mirmiran, Azadbakht, & Azizi, 2006; Mirmiran, Azadbakht, Esmaillzadeh, & Azizi, 2004), Vietnam (Ogle *et al.*, 2001) and Sri Lanka (Jayawardena *et al.*, 2013), rather than developed countries. The general consensus from these studies is that measures of dietary and food variety give good indication of nutritional adequacy in vulnerable population groups (Hatloy *et al.*, 1998; Mirmiran *et al.*, 2006; Ogle *et al.*, 2001; Oldewage-Theron & Kruger, 2011; Steyn *et al.*, 2006). See table 2.2 for previous studies on dietary diversity in developing countries.

Dietary assessment methods are able to measure the nutrient adequacy of diets. Food variety scores (FVSs) and dietary diversity scores (DDSs) were used to predict nutritional adequacy of children's diets in Mali, West Africa (Hatloy *et al.*, 1998). This was a validation study testing whether or not dietary diversity scores were accurate and truly able to measure nutritional adequacy. The population group was described as illiterate, and it was the norm for them to eat from a shared bowl. Research assistants were trained to collect dietary data, and spent nine hours per day in each household to obtain three-day weighed food records for 77 participants. They found the FVS, or average number of individual food items consumed, was 20.5 out of a possible 75 foods. The DDS, or average number of food groups consumed, was 5.8 out of a total of eight food groups. It is not pertinent to know the actual results here, although it is useful to know that they acquired these results through use of food records. Also, when they compared dietary diversity measures with validation scores, they were able to determine that dietary diversity measures were significantly associated with nutrient adequacy. They concluded that simple food item and food group counts are able to identify vulnerable groups in a setting where people eat from a shared bowl. Studies based in Vietnam and South Africa (Ogle *et al.*, 2001; Oldewage-Theron & Kruger, 2011) also used both single food counts and food group counts similar to those described above and found them to be good indicators of nutrient adequacy. A study on adolescents in Iran used DDS only to investigate dietary diversity and dietary adequacy (Mirmiran *et al.*, 2006). They found DDS to be an appropriate tool to evaluate nutrient adequacy, but felt further indices, such as the diet quality index (DQI) which assesses the diets' ablilty to meet recommended intakes of a healthy diet (Drewnowski *et al.*, 1997) would be necessary to assess overall dietary adequacy (in addition to nutrient adequacy) as it incorporates other dietary variables, such as whether the diet meet fat and sodium recommendations.

Minimal research on dietary diversity has also been conducted in developed countries. See table 2.3 for previous dietary diversity studies conducted in developed countries. Drewnowski *et al.* (1997) assessed dietary diversity in America, using a different types of dietary diversity score. In this study, participants completed a 24-hour recall interview, followed by a consecutive 14-day food record. A dietary variety score (DVS) was created based on 113 foods, which was the count of different food items consumed over the reference period (similar to FVS). They also developed a cumulative DVS, and this measure's function was to be an indicator of the participants' entire food repertoire. Lastly, the diet quality index (DQI) was also constructed in order to compare participant's intakes with the U.S. dietary recommended intakes. This last index was based on a point system where points were given if the diet met healthy eating criteria, for example a point was given if the diet had less than 30% of overall energy contributed from fat. The results of the study showed that the number of food items rapidly increases over the first three days, then at day 10-14, intake is relatively flat, suggesting that individual food count does not alter much after this length of time. This research does provide practical advice for determining an optimal reference period when assessing dietary diversity. There was no relationship between the DVS and DQI, suggesting these scores are not able to measure dietary quality.

Another study in America found that interval three-day 24-hour recalls are more accurate than consecutive three-day 24-hour recalls, but both were not truly reflective of dietary diversity as measured by 15 days of consecutive 24-hour recalls (Falciglia *et al.*, 2009).

Where dietary diversity is assessed in developing countries, often only nutritious food groups are included in the analysis (Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011; Steyn *et al.*, 2006). However, one dietary diversity study conducted in Vietnam did include two discretionary food groups, which were sauces; and beverages, biscuits and sweets. In developed countries, discretionary food items and food groups are included in dietary diversity analysis. In America, the labelling of food groups was approached differently (see tables 2.3), but they did include discretionary food groups, such as sweets and snacks (McCrory *et al.*, 1999). Similarly, Drewnowski *et al.* (1997) developed a dietary diversity measure which incorporated elements of discretionary food consumption.

Table 2.2 – Details of studies investigating dietary diversity in developing countries

Author	Country	Number of participants, and participant characteristics	Topic of investigation	Dietary assessment method and reference period	Dietary diversity measures used	Analysis approach	Main findings/outcomes	Conclusion
Hatloy *et al.* (1998)	Mali	77 children, <5 years	Whether food item and food group counts predict nutritional adequacy of children's diets in a poor country	Weighed food record for 2-3 days	Single food indicator FVS (75 food items); and food group indicator DDS (8 groups: staples, vegetables, milk, meat, fish, egg, fruits, green leaves)	NAR and MAR for 10 nutrients; different FVS and DDS cut-off points tested for sensitivity and specificity Linear regression was used in the sensitivity and specificity analysis to estimate MAR scores at different levels of DDS and FVS	1. Mean FVS 20.5; mean DDS 5.8. 2. Significant correlations between FVS and DDS for vitamins C, A and fat 3. Significant correlations between MAR and FVS r=0.33, and MAR and DDS r=0.39 4.DDS a stronger determinant of MAR (nutrient adequacy) than FVS 5. Cut-off points with most sensitivity and specificity: 23 for FVS, and 6 for DDS	DDS are a good assessment of nutritional adequacy and can identify vulnerable groups in areas where people eat from a shared bowl
Ogle *et al.* (2001)	Vietnam	196 adult women, 19-60 years	Association between food variety and nutrient intake/health status in rural women in two regions, with emphasis on significance of wild vegetables	7-day FFQ	FVS (>120 foods); and DDS which included discretionary food groups (12 groups: cereals; starchy roots; green leafy vegetables; other vegetables; fish and seafood; meat; eggs; nuts and legumes; fruit and fruit juice; oils and fats; sauces;	Intake of 13 nutrients, MARs, and biochemical parameters Created tertiles of FVS; compared highest variety with lowest variety tertiles with t-tests and ANOVA to examine differences in nutrient intakes and MARs. Multiple	1. High FVS (≥ 21) had significantly higher nutrient intakes than low FVS (≤15) 2. High DDS (≥8) significantly associated with higher MARs for energy and 4 nutrients 3. In one of two regions, high FVS group had higher nutrient density 4. Analysis of food variety can be used to predict nutrient intake and nutrient adequacy 5. Wild vegetables contributed significantly to	FVS is a useful tool for predicting nutrient adequacy and assessing the role of wild vegetables in the diet

Table 2.2 – Details of studies investigating dietary diversity in developing countries

Author	Country	Number of participants, and participant characteristics	Topic of investigation	Dietary assessment method and reference period	Dietary diversity measures used	Analysis approach	Main findings/outcomes	Conclusion
					beverages, biscuits and sweets)	regression to test differences in number of wild vegetables, MAR and nutrition/health status.	micronutrient intakes	
Rose, Meershoek, Ismael, and McEwan (2002)	Mozambi-que	388 households, total of 1140 individuals	Evaluation of a tool designed to describe household dietary intakes	Diet Assessment Tool, based on a simple 24-hour recall	Scoring system where certain items are given points ranging from one to four. Score of ≥20 was classified as acceptable quality; 12-19 as low quality; and 12 ≤ very low quality	DQI, also with a point system, from the 24-hour recall. Looked at energy, protein, vitamin A and iron One-way ANOVA used to determine whether tool classified groups correctly	1. Tool was associated with DQI for all nutrients (apart from vitamin A) 2. Performance of tool improved when the cut-off values raised from 20 to 23 points	The tool was able to describe dietary intake in Mozambican households
Torheim *et al.* (2004)	Mali	502 men and women, 15-45 years	Association between dietary diversity and nutrient adequacy	7-day QFFQ	FVS (76 food items); and DDS (10 food groups: cereals; legumes; oil and sugar; fruit; vegetables; meat; milk; fish; eggs; and green leaves)	NARs and MAR for energy and nine nutrients from previously validated QFFQ Linear regression models were used to assess the association between MAR and DDS and FVS	1. Mean FVS was 23, mean DDS was 7.8 2. Mean MAR was 0.87 3. Significant correlations between MAR and FVS r=0.34, and MAR and DDS r=0.30 3.FVS explained variation in MAR more than DDS	Dietary diversity is able to indicate nutrient adequacy in rural Mali

Table 2.2 – Details of studies investigating dietary diversity in developing countries

Author	Country	Number of participants, and participant characteristics	Topic of investigation	Dietary assessment method and reference period	Dietary diversity measures used	Analysis approach	Main findings/outcomes	Conclusion
Steyn *et al.* (2006)	South Africa	2200 children, 1-8 years	Whether FVS and/or DDS are able to indicate nutrient adequacy in South African children	24-hour recall covering one day (three 24-hour recalls conducted on 10% of participants)	FVS (45 food items); and DDS (9 food groups: cereals, roots and tubers; vitamin-A-rich fruits and vegetables; other fruit; other vegetables; legumes and nuts; meat, poultry and fish; fats and oils; dairy; and eggs)	FFQ used to calculate NARs for 11 micronutrients, energy and protein; MAR calculated for 11 micronutrients Correlation coefficients used to compare DDS with MAR and NARs	1. Mean FVS was 5.5, mean DDS was 3.6 2. Mean MAR was 0.50 3. Significant correlations between MAR and FVS r=.726, and MAR and DDS r=.657 4.Dietary diversity related to height-for-age and weight-for-age z-scores 5. Cut-off points with most sensitivity and specificity: 6 for FVS, 4 for DDS	DDS and FVS are simple and quick indicators of micronutrient adequacy
Mirmiran *et al.* (2004)	Iran	304 adolescents, 10-18 years	Determine dietary diversity and its relationship with nutrient adequacy	Two 24-hour recalls	DDS (5 food groups, including grain, vegetable, fruit, meat and dairy; and 23 sub-groups)	NARs and MAR for energy, protein, fat and10 micronutrients Correlation coefficients used to compare DDS with MAR and NARs	1. Mean DDS was 6.25 2. Significant correlations between MAR and DDS r=0.42. 3. Higher DDS associated with greater BMI	DDS was able to assess nutrient adequacy in adolescents
Arimond *et al.* (2010)	Burkina Faso, Mali, Mozambi-que, Banglade-sh, Philippin-es	Used 5 existing data sets of different sizes, ~500 participants, 15-49 years	Assessment of ability of dietary diversity indicators to represent micronutrients adequacy of	Two 24 hour recalls	FGIs which varied in the level of food group aggregation and in minimum quantity of food consumption required for food group to be	Probability adequacy, and mean probability of adequacy for 11 micronutrient s Correlation coefficients and regression analysis	1. Higher FGI scores associated with higher mean probability of adequacy 2. Correlations between FGI scores and MPA higher when 15g minimum quantity used. 3. No FGI could be identified for universal use	Simple FGI have the ability to indicate micronutrient adequacy in resource-poor settings

Table 2.2 – Details of studies investigating dietary diversity in developing countries

Author	Country	Number of participants, and participant characteristics	Topic of investigation	Dietary assessment method and reference period	Dietary diversity measures used	Analysis approach	Main findings/outcomes	Conclusion
			populations		included in the score. FGIs either had 6, 9, 13 or 21 food groups. The two minimum quantities used were 1g and 15g. All nutritious food groups	were used to investigate relationship between FGI and mean probability of adequacy		
Oldewage-Theron and Kruger (2011)	South Africa	426 women from 357 households in a peri-urban settlement	Assessment of food security in black women through food accessibility; investigated measures of dietary diversity and coping strategies to manage poverty and hunger	One-week QFFQ	FVS (40 food items); and FGDS (similar to DDS) (9 nutritious food groups: cereals, legumes, flesh products, eggs, dairy, vegetables, fruits, vitamin A-rich group, fat group)	NARs and MAR for energy, protein, carbohydrates and 21 micronutrients calculated from 24 hour recall data Correlation coefficients used to compare FGDS with NARs and MAR. Specificity and sensitivity of FVS cut-off values tested against MAR	1. Intake of all nutrients (except carbohydrates) deficient 2. Mean FVS was 3, and mean FGDS was 3. 3. Significant correlations between MAR and FVS r=.224, and MAR and DDS r=.224 4. Cut-off points with most sensitivity and specificity: 5 for FVS 5. FVS and FGDS/DDS good indicators of dietary adequacy	Limited access to food and food variety results in inadequate nutrient intakes. Dietary diversity provide good indication of dietary adequacy and diet quality in poverty-stricken communities

Table 2.2 – Details of studies investigating dietary diversity in developing countries

Author	Country	Number of participants, and participant characteristics	Topic of investigation	Dietary assessment method and reference period	Dietary diversity measures used	Analysis approach	Main findings/outcomes	Conclusion
Fujita *et al.* (2012)	Kenya	214 breastfeeding women, 18-46 years	Investigate ability of DDS to predict micronutrient status, with focus on serum vitamin A	24-hour dietary recall	DDS (10 food groups: cereals/tubers; meat/poultry/fish; vitamin A-rich fruits and vegetables; other vegetables; other fruit; oils and fats; dairy; eggs; pulses/nuts; and other foods)	Vitamin A status assessed by blood samples Regression to examine relationship between DDS and serum retinol concentration and its ability to predict vitamin A insufficiency	1. Mean DDS was 5 2. DDS had significant positive effect on serum retinol 3. DDS a significant negative predictor of vitamin insufficiency	Increasing dietary diversity improves vitamin A status, and DDS has potential to predict vitamin A status
Mirmiran *et al.* (2006)	Iran	286 females, 18-80 years	Whether dietary diversity can reflect probability of nutrient adequacy	Two 24-hour recalls	DDS (five food groups: bread/grains, vegetables, fruits, meats, dairy; which were divided into 23 subgroups)	NAR and MAR for energy, protein, fat and 10 micronutrients Correlation coefficients to assess association between dietary diversity and NAR and MAR. Linear regression used to assess which food groups most important to NAR and MAR	1. Mean DDS was 6 2. MAR was 0.50 3. Energy intake was strong predictor of MAR 4. Dairy dietary diversity had strongest association with MAR 5. DDS significantly associated with specific NAR	DDS can indicate specific nutrient adequacy

Table 2.2 – Details of studies investigating dietary diversity in developing countries

Author	Country	Number of participants, and participant characteristics	Topic of investigation	Dietary assessment method and reference period	Dietary diversity measures used	Analysis approach	Main findings/outcomes	Conclusion
Jayawardena *et al.* (2013)	Sri Lanka	600 adults, >18 years	Association between dietary diversity and obesity	24-hour diet recall	FVS (no maximum value); DDS (12 food groups: starch; vegetables; green leafy vegetables; fruits; fish; meat; legumes; milk; beverages; oils and fats; sweets and miscellaneous); DDSP (portion sizes included; 7 food groups: starch; vegetables, green leady vegetables, meat, pulses and fruit)	Energy intake calculated from diet recall Independent samples test and ANOVA used to compare means	1. Mean DDS: men 6.23, women 6.50 2. DDSP: men 3.26, women 3.17 3. FVS: men 9.55, women 10.24 4. Obese and abdominal obesity associated with higher DDS 5. Dietary diversity increased as BMI, waist circumference and energy consumption increased	Dietary diversity is associated with obesity in Sri Lankan adults

FVS, food variety score; DDS, dietary diversity score; NAR, nutrient adequacy ratio; MAR, mean adequacy ratio; DQI, diet quality index; FFQ, food frequency questionnaire; QFFQ, quantitative FFQ; FGI, food group diversity indicators; FGDS, food group diversity score; DDSP, dietary diversity score with portions

Table 2.3 – Details of studies investigating dietary diversity in developed countries

Author	Country	Number of participants, and participant characteristics	Topic of investigation	Dietary assessment method and reference period	Dietary diversity measures used	Analysis approach	Main findings/outcomes	Conclusion
Foote *et al.* (2004)	America	4969 men and 4800 women, ≥ 19 years	Whether a commodity-based measure of dietary diversity was related to nutrient adequacy	24-hour recall	Scores were developed based on a HEI, FGP servings and the type of agricultural commodity	NAR and MAR for 15 micronutrients Correlation coefficients to assess the association of FGP and dietary diversity with the MAR	1. Average FVS: 8 for men, 7.3 for women 2. All FGP servings and variety counts were significantly correlated with MAR (except for meat/protein servings in men) 3. Overall FVS better correlated with the MAR than the within-food group variety counts	Consumption of different commodities contributed to mean probability of nutrient adequacy
Drewnowski *et al.* (1997)	America	24 young adults (20-30 years) and 24 older adults (60-75 years); 24 men, 24 women	Development of a new measure of dietary diversity, DVS, and whether it's related to diet quality	14 consecutive day food record, and a 24-hour recall	DVS, a cumulative score of food items eaten (113 food items); similar to FVS	Dietary quality index (DQI) which is based on a point system using US dietary recommendations Differences in means assessed by *t* tests, differences in distributions assessed using least likelihood x^2	1. DVS increased with time 2. DVS slope increases sharply between days one and three 3. DVS slope only small increases between day 10 and 15, suggesting food repertoire met by 14 days 4. No relationship between the DVS and DQI 5. Older participants had higher DVS compared to younger participants	Older adults have more dietary diversity than younger adults, and DVS unable to measure diet quality

Table 2.3 – Details of studies investigating dietary diversity in developed countries

Author	Country	Number of participants, and participant characteristics	Topic of investigation	Dietary assessment method and reference period	Dietary diversity measures used	Analysis approach	Main findings/outcomes	Conclusion
McCrory *et al.* (1999)	America	71 men and women, 20-80 years	Investigate whether within food group dietary variety influences energy intake and body fat	Six-month FFQ	Dietary variety within food groups (10 food groups: breakfast foods; lunch and dinner entrees; sweets, snacks, and carbohydrates; condiments; fruits; vegetables; energy-containing beverages; dairy products; breakfast food condiments; and beverage condiments); variety calculated as % of different food items consumed within each food group	Energy intake calculated from FFQ and reporting of usual portion size Correlation coefficients to assess association between dietary variety and energy intake. Linear regression analysis was used to assess the association between dietary diversity and body fatness	1. Mean dietary variety for 10 food groups ranged from 32% to 80% 2. Significant correlation found between energy intake within food group diversity, r=0.27-0.56 3. Dietary variety in sweets, snacks, condiments, entrees and carbohydrates (as a group) correlated with body fatness, partial r=0.38. Vegetables negatively associated with body fatness, r=-0.39	High variety of sweets, snacks, condiments, entrees and carbohydrates and low vegetable variety promotes increased energy intake and body fatness

Table 2.3 – Details of studies investigating dietary diversity in developed countries

Author	Country	Number of participants, and participant characteristics	Topic of investigation	Dietary assessment method and reference period	Dietary diversity measures used	Analysis approach	Main findings/outcomes	Conclusion
Falciglia *et al.* (2009)	America	72 children, 9-12 years	Explore whether three 24 hour dietary recalls would predict variety similar to 15 consecutive dietary recalls, and whether 3 days (consecutive vs. interval days) could predict 15-day DVS	Three 24 hour recalls and 25 consecutive 24 hour recalls	DVS, a cumulative score of food items eaten and based on principles of HEI	3 cumulative DVSs estimated: one for 15 consecutive days, 3 consecutive days (first 3 days), and 3 days separately by ~5 day intervals Linear regression to predict models of 15-day DVS. Ability of model to predict 15-day DVS assessed by comparisons of means and correlation coefficients	1. Cumulative 15-day DVS 43.3 2. Three consecutive days DVS 18.6 3. Three interval days DVS 20.4 4. Three days are dietary data not reflective of true dietary variety 5. If using three days, interval days more accurate than consecutive days at predicting 15-day food variety 6.DVS increased sharply from days one to three	Dietary data over 3 days can estimate dietary variety in children

NAR, nutrient adequacy ratio; MAR, mean adequacy ratio ; HEI, healthy eating index; FGP, food guide pyramid; DVS, dietary variety score; DQI, dietary quality index; FFQ, food frequency questionnaire

2.1.5 Importance and relevance of dietary diversity

Dietary diversity has been recognised as a key component of nutritionally adequate diets. Many international nutritional guidelines contain the recommendation to consume a variety of foods, similar to that in New Zealand. The second of five guidelines for Australian adults is to consume a range of nutritious foods from five food groups (National Health and Medical Research Council, 2013). The first of the eleven food-based dietary guidelines for South African's over the age of seven is to enjoy a variety of foods (Department of Health. Directorate of Nutrition, 2007). The most recent dietary guidelines for American's are more specific about how to include variety in the diet. They have a range of recommendations, with more than one of them being linked to variety. For example, not only do they recommend eating a variety of vegetables, but they also encourage including a range of different coloured vegetables (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). These guidelines show that it is known that variety is an essential component of nutritionally adequate diets.

Understanding nutrition guidelines/messages can be difficult. Research on children's understanding of nutrition messages found that younger children were less likely to understand the guideline "eat a variety of food" (Lytle *et al.*, 1997). As children get older, they have a greater understanding of dietary variety and an improved ability to explain that eating a variety means eating food from all of the food groups. However, even some adult consumers interpret dietary variety to mean intake of food in different forms or flavours that are not regarded as healthy, such as different types of candy bars (Foote *et al.*, 2004). Depending on the type of food consumed, variety of food items and food groups can impact health in different ways. An illustration of this is the consumption of a variety of foods from the food group "sweets, snacks, condiments, entrees and carbohydrates" which has been associated with higher body fat levels (McCrory *et al.*, 1999). In that same study, the intake of a variety of vegetables was linked to reduced body fatness. The recommendation of eating a variety of foods needs to be conveyed in a way that people know to eat a variety of food types that are beneficial for health and not a variety of foods that are harmful to health.

Diets that are monotonous and contain large amounts of starchy staples can lack essential micronutrients, and these diets contribute to micronutrient deficiencies and consequent malnutrition (Mason, Lofti, Dalmiya, Sethuraman, & Deitchler, 2001). World prevalence of micronutrient malnutrition is high, with about one-third of the world population being affected by a range of vitamin and mineral deficiencies (Mason *et al.*, 2001). Greater variety of

food groups included in diets has been positively correlated with adequate macronutrient and micronutrient content of diets in adults (Arimond *et al.*, 2010; Foote *et al.*, 2004; Fujita *et al.*, 2012; Ogle *et al.*, 2001). In addition to this, dietary diversity and its association with health outcomes has been researched. Variety in food intake has been shown to decrease the prevalence of cancer and cardiovascular disease (CVD) (Jansen *et al.*, 2004; Kant, Schatzkin, & Ziegler, 1995). Women and men aged 25-74 years were found to have increased risk of death from CVD and cancer with lower dietary diversity (Kant *et al.*, 1995). Another study exemplifying the relationship between dietary diversity and health was carried out on men and women, and it investigated the relationship between dietary diversity and mortality (Kant *et al.*, 1993). The results showed that a low dietary diversity score was also associated with an increased risk of all-cause mortality, irrelevant of age, gender, ethnicity, smoking status, education and income. Interestingly, they also showed that greater dietary diversity was linked to lower BMI in women.

Food variety is also important for health of infants and children. In infants, increasing the diversity of foods introduced may reduce the risk of incidence of asthma and food allergy (Roduit *et al.*, 2014). Children with lower dietary diversity are more likely to be undernourished (have signs of wasting, stunting, and/or be underweight) than those with high dietary diversity (Olumakaiye, 2013). Steyn *et al.* (2006) investigated nutrient adequacy in South African children's diets. They found that dietary diversity was strongly related to the indicators of growth (height-for age and weight-for age). Steyn *et al.* (2006) concluded that a DDS of seven or less (consumption of 7 or less food groups) would be likely to cause growth indicator z-scores to be below zero. A suggestion from this study was that health-care workers in South Africa could use dietary diversity scores as a rapid and effective way to measure nutrient adequacy of children's diets. In future, DDQs may be used by health care workers to assess potential health outcomes and nutritional status.

Dietary diversity measurement has been used to evaluate food consumption in a household, which then reflects that household's access to a range of foods (FAO, 2011). Household access to food is thought to be related to socio-economic status, as a more financially stable household is assumed to have easier and greater access to food. In addition to this, as income increases it seems reasonable to believe that people would diversify their diet as their income increases as it becomes more affordable and, because greater variety is more enjoyable and palatable. Research has provided evidence for these assumptions, with socio-economic status and household food security being related to increased dietary diversity (Hatloy, Hallund,

Diarra, & Oshaug, 2000; Hoddinott & Yohannes, 2002). Interestingly, Hoddinott and Yohannes (2002) found that as households increase the diversity of their diets, they tend to eat more prestigious and dispensable foods, such as fruits and vegetables, rather than eating more variety from staple food groups, such as grains. The effect of increasing diversity of diets on consumption of staple and non-staple foods groups in the New Zealand population is unknown.

Food insecurity is when availability of food is limited or not certain, the food is not nutritious, safe or the amount is insufficient, and/or this food cannot be acquired in a socially-acceptable manner (Carlson, Andrews, & Bickel, 1999). Lower dietary diversity has been associated with household food insecurity (Hoddinott & Yohannes, 2002). In New Zealand, it has been reported that food variety is often limited due to lack of money in 7.6% of households, and is sometimes limited for 22.% of households (Ministry of Health and Otago of University 2011). A study on Pacific families living in New Zealand explored the variety of foods purchased when dealing with financial constraints. They found that the variety of food intake was reduced by lack of money in 39.3% of the study population, and that families still purchased, bread, milk, meat and chicken, but reduced purchasing of alcohol, fizzy drinks, ice cream and juice (Rush, Puniani, Snowling, & Paterson, 2007). This study concluded that food security is a major problem in Pacific families living in New Zealand. With dietary diversity being able to measure nutrient adequacy and food security (FAO, 2011; Hoddinott & Yohannes, 2002; Ruel, 2003), future research could be conducted using DDQs to determine the dietary diversity and nutrient status of individuals and explore how this relates to factors like income and accessibility to food in New Zealand. Measurement of dietary diversity may be a promising method to assess food security in environments where resources are limited, as a DDQ would be cheaper and easier to implement compared to traditional methods of dietary assessment (Ruel, 2003).

2.1.6 Disadvantages of DDQ

Similar to FFQs (if unquantified), a limitation of a DDQ is that it does not account for total energy consumption. Total food and energy intake might be implicated in disease outcome, therefore, it may be a confounder of the effects of individual foods or nutrients (Willet, 1998). Without assessment of quantities of food consumed, dietary diversity is not able to assess the true scope of diets because although the intake of foods items and food groups is assessed, the quantity and portion sizes of foods items consumed is needed to provide a "full picture" (Dixon, Cronin, & Krebs-Smith, 2001).

Another disadvantage of dietary diversity lies within the measures produced. The measures provide basic counts of food and food groups consumed and this indicates the level of variety in the diet, but unfortunately it is only a number and this does not indicate which food groups are included in the score (Dixon *et al.*, 2001). There is also the issue that the scores assume that it is preferable for food to be consumed from all food groups. However inclusion of unhealthy food groups in the score means that DDS would be higher, but this may not correspond with a more healthy diet. Also, diets that do not include certain food groups can still be nutritionally adequate, for example a diet where milk and milk products are excluded (Dixon *et al.*, 2001).

It can also be difficult to compare results between studies on dietary diversity as each study has its own definition of measures (Hatloy *et al.*, 1998). This leads to one of the main reasons for the need for further research on dietary diversity: contribution to methods of dietary diversity measurement to provide consistency.

The completion of the DDQ, similar to other dietary assessment methods such as the FFQ and 24-hour recall, participants need to rely on memory (Black, 2001). This may lead to under-reporting of food and energy intake and inaccuracies. Like the FFQ (Lee & Nieman, 2003), meal pattern data is not provided by the DDQ, as it only provides the number of food items and food groups consumed, not the times they were consumed or if they were included as part of a meal or snack.

2.1.7 Need for a DDQ – Gap in the research

Lack of diversity in diets is a serious problem in developing countries, and therefore much of the research on dietary diversity has been based on populations in these countries, rather than developed countries. Research in developing countries found that changing from a repetitive diet to a diet with a variety of food lead to improved nutrient intake, food security and better health outcomes (Ruel, 2003). Increasing dietary diversity is frequently associated with increased food intake, and so consequently is also related to higher levels of energy. However, at the other end of the spectrum in developed countries, there may be a link between dietary variety and obesity. Could encouraging dietary variety be promoting overconsumption of energy and hence be contributing to obesity? Excessive intake of discretionary foods in populations where there is high food accessibility and availability needs to be considered. Although it is not a developed country, a recent study on Sri Lankan men found that adults who were obese or had abdominal obesity had significantly more variety in their diets compared to those who were not obese (Jayawardena *et al.*, 2013). Also, a study in Iran found

that higher DDS were associated with greater BMIs in women (Mirmiran *et al.*, 2004). An American study on dietary variety found strong associations between energy intake and dietary variety, food group intakes, and nutrient adequacy. They discussed that reduced dietary diversity may potentially be able to reduce energy intake and hence reduce the risk of obesity (Foote *et al.*, 2004). However this also depends on what types of foods are included in the analysis of relationship between energy intake and dietary diversity. Thus, they also point out that recommendations to consumers should emphasise the importance of maintaining energy balance and alter diet variety within this energy balance (Foote *et al.*, 2004).

In the New Zealand society there is high availability of an extensive range of food, and healthy food is more expensive than 'regular' food (Wang *et al.*, 2010), which means people may be more likely to consume unhealthy foods. Additionally, in New Zealand there is high food availability and accessibility, especially of unhealthy foods (Jenkin, Signal, & Thomson, 2011). There needs to be an investigation on what this effect is having on dietary diversity and nutrient adequacy in the New Zealand population. Development of a DDQ tool which is able to assess dietary diversity in a New Zealand population group will aid this much-needed research in a developed country where food is highly accessible and available.

Not only does lack of money affect an individuals' dietary diversity in developing countries, it is also a contributing factor to dietary diversity in developed countries, including New Zealand. A higher proportion of Māori compared to Europeans in New Zealand experience reduced household food variety, which is attributed to lack of money (Ministry of Health, 2003a). Pacific Island families living in New Zealand also experience food insecurity and reduced food variety when experiencing financial difficulties (Rush *et al.*, 2007). With increasing rates of obesity and diabetes in New Zealand, and poorer health in Māori, Pacific and people living in socioeconomically deprived areas (Ministry of Health, 2012), it is important to assess dietary diversity in these groups and investigate how this is impacting their overall health and well-being. Development and validation of a DDQ in the New Zealand population could be used to assess dietary variety in the Māori and Pacific Island populations to determine the effect lack of money is having on their diets and potentially plan interventions to improve their dietary variety and health.

Women of reproductive age, among other population groups, are one of the most likely groups to suffer from nutrient deficiencies (Arimond *et al.*, 2010). Pregnancy and lactation means women have high nutrient demands, especially women in developing countries. Although more severe in developing countries, it is clear that micronutrient deficiencies

amongst women are a global problem (Kennedy & Meyers, 2005). Studying dietary diversity in women of reproductive age is necessary as this group is at high risk of having nutrient inadequacy, and limited studies have been conducted on dietary diversity as a measure of diet quality in women of reproductive age (Arimond *et al.*, 2010).

The New Zealand Ministry of Health has a guideline that encourages New Zealanders to include a variety of nutritious foods from the major food groups, but there is no quantification to the guideline and health workers may be unsure on how to interpret this guideline (Ministry of Health, 2003a). Further research on dietary diversity and DDQ development will contribute to production of future guidelines that are meaningful.

Previous studies used 24 hour recalls or food records to calculate dietary diversity. Food records yield a high number of food codes, which needs to be reduced to a lower number of foods in order to make it more manageable (Drewnowski *et al.*, 1997). Instead researchers could obtain a count directly from a specially developed DDQ. There is a need for a questionnaire with all the possible foods that could potentially be consumed listed so that in future, researchers do not have to go through data to code foods or to decide on foods to be included or excluded in food lists - a timely process. A DDQ would provide another dietary assessment method that is quick, easy-to-administer, has low respondent burden and can assess nutritional adequacy. It is not feasible to be carrying out lengthy dietary assessment in primary health care settings to determine dietary variety or nutrient adequacy. Health care workers are also in need of a quick, simple and accurate dietary assessment method to evaluate of dietary intake (Steyn *et al.*, 2006). Interventions can be planned to target population groups where nutrient deficiencies are highly prevalent based on dietary diversity measures. Validation of dietary diversity measures created from the developed DDQ will contribute to progression towards standardised methods in developed countries.

2.2 Dietary Assessment

2.2.1 Nutrition and dietary assessment

Nutritional assessment has been defined as “the interpretation of information from dietary, laboratory, anthropometric and clinical studies” (Gibson, 2005, p. 2). The interpretation of this information is used to determine nutritional status in individuals and population groups. Nutrition assessment was first designed to explain the nutritional status of national populations, and is still used for this purpose. However, now nutritional assessment is also needed for the identification of individuals and populations at nutritional risk, to establish

what nutrition intervention is required to prevent and reduce this risk, and to monitor the intervention (Lee & Nieman, 2003).

The specific uses for nutritional assessment are varied. For example, nutrition assessment is essential in the hospital setting, as nutrition has a critical role in the recovery from illness and injury (Gibson, 2005). Patients with protein energy malnutrition (PEM) are more likely to have longer hospital stays, greater occurrence of complications and are at higher risk of mortality (Berry & Braunschweig, 1998; Bickford, Brugler, Dolsen, & Vickery, 1999; Hensrud, 1999; Jeejeebhoy, 1998), which all increase treatment and healthcare costs. Being able to identify patients in hospital that have high nutrition risk is therefore necessary to contain cost of medical treatments and health care (Posthauer, Dorse, & Foiles, 1994). The management of diabetes and associated nutrition recommendations for diabetes also requires nutritional assessment (Franz *et al.*, 2002). This is because nutritional goals for people with diabetes arise from information gathered from dietary history, estimated nutrient intake and clinical data. Similarly, dietary assessment plays a big role in heart disease and cancer prevention and management, with both being linked to food intake and lifestyle factors (Doll & Peto, 1981; Grundy *et al.*, 2000). Another demonstration for the use of nutritional assessment is for weight management. Surveys at a national levels provide data on overweight and obesity prevalence; anthropometry allows changes in body fat mass and lean mass stores to be measured; and dietary methods provide information on diet quality and energy intake (Lee & Nieman, 2003). Another key use for nutritional assessment is nutrition monitoring. Nutrition monitoring includes the activities undertaken to provide ongoing information on nutrition conditions present in populations for the purpose of planning and analysing policies and programmes developed for nutrition conditions (Mason, Habicht, Valverde, & Tabatabai, 1984). Therefore, nutritional monitoring addresses factors such as nutritional status, food intake, food and health knowledge, and food supply (Migasena, 1981), and nutritional assessment expertise is required to administer techniques (e.g. surveys) to gather this information (Lee & Nieman, 2003). Finally, another example for the use of nutritional assessment is in nutritional epidemiology. Nutrition-related research conducted by universities, industry and government requires at least some involvement of nutrition assessment (Lee & Nieman, 2003). It is essential to understand the theory behind and strength and weaknesses of different assessment methods. For example, epidemiologists examining the influence of diet on weight loss and body composition needs to understand the strengths and weaknesses of nutrition assessment methods available in order to decide which to methods to use to monitor food and energy intake, changes in weight and changes in body fat percent.

The procedures within nutrition assessment to gain dietary information are termed dietary assessment methods or tools. Dietary assessment methods are used to gather information on food consumption, such as quantity of food, frequency of eating, types of food eaten, quality of food consumed and eating habits (Biro *et al.*, 2002). There are a range of dietary assessment methods available and ultimately their reason for use is to improve health (Stamler, 1994). More specific reasons for measuring diet and food consumption include estimation of nutrient intakes, assessment of food supply, formulation and evaluation of government health policies, epidemiological research, offering individuals dietetic advice, and even commercial purposes (Black, 2001; Lee & Nieman, 2003). Each of these different situations has different requirements in regards to the type of the dietary data gathered via dietary assessment methods. Different methods to assess food consumption are grouped depending on what kind of data is required and at what level of food consumption data is needed, whether it be at the individual, household or national level (Gibson, 2005).

The collection of dietary data that is accurate and reliable is difficult and complicated. The area of nutritional science has long been facing the dilemma of how to accurately record dietary intake and determine habitual intake of humans (Blundell, 2000). Assessment of diet is difficult due to many reasons, including day-to-day variability in food intake, misreporting of intake, variation in daily intake of meals and snacks, the thousands of foods and food products available, changes in season, presence of confounders (such as under-reporting), and limitations associated with use of nutrient composition tables (Black, 2001; Gibson, 2005; Roman-Vinas *et al.*, 2009). There is not one dietary assessment method that is the best method, and measurement of diet will always have some degree of error (Beaton, 1994). Even the weighed food record, which has been labelled the "gold standard" method of dietary assessment (Gibson, 2005), has limitations such as high participant burden and decreasing reliability over time due to increasing participant fatigue (Biro *et al.*, 2002).

With different methods of dietary assessment available, the decision needs to be made on which method is the most appropriate for use. The choice of method depends on study objectives, the purpose of the dietary data collection, the setting in which the assessment is carried out (e.g. developing country), available resources, food and nutrients of interest, the time frame being assessed, the characteristics of the population (such as age and literacy levels), and whether individual or group data is being collected (Biro *et al.*, 2002). In large-scale epidemiological studies there is less focus on individual intakes because the focus is on getting an overview of the populations' dietary habits and intake over long periods of time. However,

in small-scale research, the focus is on the finer details of individual intake. In the case of a dietitian offering individual advice, the type of the dietary data needed depends on the patient and the patient's condition (Black, 2001). An example of this is in a patient with cardiovascular disease, where the dietary assessment method needs to be flexible to allow more information to be gathered specifically on sources, types and amounts of fat intake, because fat intake is implicated in cardiovascular health (National Health and Medical Research Council, 2006). An example of dietary assessment being used in epidemiological research is a study on the prevention of osteoporosis in women. With poor intake calcium being linked to osteoporosis (National Health and Medical Research Council, 2006), a dietary assessment method that can assess usual diet patterns and intake of calcium-rich foods over time in a large group of women would be necessary.

2.2.2 Types of dietary assessment methods

There are several commonly used types of dietary assessment methods. Dietary assessment methods are classified based on their various characteristics. These characteristics include the timeframe that measurement occurs (retrospectively or prospectively), the period of time being assessed (short or long term), and the type of data gathered (quantitative or qualitative) (Buzzard, 1994; Gibson, 2005; Lee & Nieman, 2003).

Dietary assessment methods can either measure diet in the past or prospectively. The only prospective dietary assessment method is food records, where the subject is required to record the food and drinks they consume at the time of consumption (Lee & Nieman, 2003). The 24-hour recall, food frequency questionnaire (FFQ), and diet history are all retrospective dietary assessment methods. Retrospective methods require participants to use their memory to recall food and drinks consumed in the past.

Short term methods measure recent food intake, usually over a number of days (Biro *et al.*, 2002), including the 24 hour recall, where food intake is recalled over the previous 24 hour period, and the dietary record, which records food intake over one or multiple days (Lee & Nieman, 2003). Long-term methods include the dietary history or FFQ, where information on usual intake and food intake patterns over previous months or years is collected (Lee & Nieman, 2003).

Dietary assessment methods are also categorised based on whether the data gathered is quantitative or qualitative. Quantitative methods measure the quantity of foods consumed (Black, 2001), for example 24-hour recalls as well as food records. Qualitative methods

measure habitual intake of food items, food groups and eating patterns (Black, 2001), such as the FFQ and diet history. The FFQ can also be altered to become quantitative by requesting participants to include the usual quantities of the food items listed consumed (Lee & Nieman, 2003). The diet history technique provides a mixture of quantitative and qualitative data.

Each dietary method has strengths and weaknesses. Table 2.4 provides a summary of the strengths and weaknesses of the most commonly used methods to obtain dietary intake data.

Disadvantages of the dietary assessment methods include the need for a skilled interviewer, the long time it takes to complete the assessment, and the high participant burden (Black, 2001). They can also be expensive if interviewer training or equipment (namely food scales) are required, and they may require technical skill in order to gather the data as well as analyse it (FAO, 2011). Development of another dietary assessment tool that is inexpensive, does not require a trained interviewer and has low participant burden would be beneficial for future research where assessment of diets is required. There is need for a tool that is quick to complete and the data that is provided from the tool is easy to assess. The tool should also reflect nutrient adequacy accurately, and ultimately contribute to assessment of nutritional status. No dietary assessment method is free of random and/or systematic errors (Gibson, 2005). However, dietary assessment should not be limited to the methods currently available, with production of new methods having the potential to cover limitations that current methods hold.

Table 2.4 – Typical dietary assessment methods and the strengths and weaknesses of each

Method	Characteristics	Description	Strengths	Weaknesses
24 hour recall	Quantitative, short term and retrospective	-Interview format where participants provide detail on type and quantity of food and drinks consumed in the previous 24 hours	-Quick and easy -Reliable due to interview format/personal contact -No literacy requirement of participant -Low participant burden -Short administration time (15-20 minutes) -Food pattern intake not altered Can be conducted by telephone	-Relies on participant memory -Needs trained interviewers for knowledge on portion sizes and interviewing skills -Potential interviewer bias -Multiple 24 hour recalls over several days are required to describe usual dietary intake -Underestimates intake
Food record (FR)	Quantitative, short term and prospective	-Self-administered record of all food and drink consumed over a specified number of days -Two types: estimated FR use household measures and food models to estimate portion sizes. Weighed FR use scales to weigh portions consumed	-Good information on individual foods consumed and eating patterns -Can provide information on food quantity, preparation and cooking methods, timing of food consumption -Fairly accurate, if participant's eating behaviour not changed -Does not rely on participant memory -Open-ended -Can vary numbers of days studied	-Requires motivated, numerate and literate participant -High participant burden and lower compliance -Food pattern can be altered by recording process -Participant's fatigue reduces record reliability, especially if carried out over greater number of days -If foods are not recorded promptly, the number of foods omitted and faults increase

Table 2.4 – Typical dietary assessment methods and the strengths and weaknesses of each

Method	Characteristics	Description	Strengths	Weaknesses
Food frequency questionnaire (FFQ)	Qualitative or quantitative (if portion sizes are included), long term and retrospective	-A self-administered questionnaire made up of a checklist of foods consumed -Includes range of frequency categories over given time periods -Quantitative FFQs (QFFQs) include usual portion sizes -Non-quantitative FFQs do not include usual portion sizes	-Low subject burden -Short completion time, but longer than the 24 hour recall -Describes usual intake -Can be used on large numbers -Self-administered/interview-based -Normal eating patterns not affected	-High literacy skills required -Meal pattern data not provided -Relies on memory -Knowledge on portion sizes needed -Poor quantification of portion sizes by participant can lead to inaccuracy -Overestimates food intake
Dietary history	Combination of qualitative and quantitative, long or short term and retrospective	-A combined method -Includes an interview to assess usual meal pattern, a 24-hour recall and a FFQ -May or may not include a three-day dietary record	-A single interview -Measures usual intake, including seasonal changes	-Requires a highly skilled interviewer, and recording can be labour intensive -Relies on participant memory -High participant burden -Participant needs complex cognitive skills -Tends to overestimate food intake -Lengthy interview process

FR, food record; FFQ, food frequency questionnaire; QFFQ, quantified food frequency questionnaire
Sources: (Biro *et al.*, 2002; Black, 2001; Gibson, 2005; Lee & Nieman, 2003; Mahan *et al.*, 2012)

2.2.3 Dietary diversity questionnaire as a new dietary assessment method

In earlier research, dietary diversity has not been assessed through actual dietary diversity questionnaires. Instead, other dietary assessment methods have been used to measure dietary diversity, including quantified FFQ (Oldewage-Theron & Kruger, 2011; Torheim *et al.*, 2003), weighed food records (Hatloy *et al.*, 1998), 24-hour recalls (Foote *et al.*, 2004; Steyn *et al.*, 2006), and large-scale surveys (Arimond *et al.*, 2010). As shown by the great variety of methods used, there has yet to be a standardised method to measure and assess dietary diversity, particularly in developed countries. See table 2.2 for a range of methods used to measure dietary diversity.

Dietary diversity questionnaires (DDQs) are a more recent dietary assessment method that have been developed and used to measure diets of either individuals or household access to food (FAO, 2011). One DDQ was previously developed for a South African population, and it consisted of a list of foods which the participants simply ticked yes or no to each food item based on whether or not they consumed it over the given reference period (Matla, 2008). Generally, DDQs are beneficial to other methods of dietary assessment because they require only a short amount of time to complete, are inexpensive to execute, are self-administered and therefore a trained interviewer is not required, and high literacy skills are not required by the respondent nor is knowledge on portion sizes (FAO, 2011; Oldewage-Theron & Kruger, 2011; Steyn *et al.*, 2006). In addition to this, respondents' food patterns are not altered by completion of the DDQ, different to that of food records where recording of food is known to influence eating patterns (Biro *et al.*, 2002). However, not all populations would suit a self-administered questionnaire, for example vulnerable groups in West and South Africa (Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011), where trained interviewers were required to collect dietary intake data. It is of utmost importance that a DDQ is developed and adapted with regards to the culture, population group and location being investigated (FAO, 2011).

2.3 Development of a DDQ

2.3.1 Guidelines for DDQ development

Food and Nutrition Technical Assistance (FANTA) Project is a cooperative agreement that aims to improve health of those individuals, families and communities at risk in poor and developing countries through supporting policies and programs around food security and nutrition. They have developed a tool to measure household dietary diversity as an indicator of household food access (Swindale & Bilinsky, 2006). Following on from this, the FAO (2011) published

international guidelines in an attempt to provide a more standardised method for the measurement of dietary diversity. These guidelines were based on the tool originally developed by FANTA and recommend using an open recall method covering a 24-hour period for their dietary data collection method. The researcher or interviewer is to record all foods and drinks consumed by the participant, and use a probing technique to ensure all foods are recalled by the participant and recorded. Each food item is then categorised into food groups depending on whether household or individual dietary diversity is being assessed. For household food diversity measurement, 16 food groups should used (cereals; white roots and tubers; vitamin-A rich vegetables and tubers; dark green leafy vegetables; other vegetables; vitamin A-rich fruits; other fruits; organ meat; flesh meats; eggs; fish and seafood; legumes, nuts and seeds; milk and milk products; oils and fats; sweets; and spices, condiments, beverages), and for individual dietary diversity measurement of nine nutritious food groups should be used (starchy staples; dark leafy green vegetables; other vitamin A-rich fruits and vegetables; other fruits and vegetables; organ meat; meat and fish; eggs; legumes, nuts and seeds; milk and milk products). From this the dietary diversity scores can be calculated. These FAO guidelines are not specific to any certain culture/ethnicity, population or setting, and hence can be easily adapted to the context which the questionnaire will be used (FAO, 2011). This guideline is vital in DDQ development. For example, illiterate communities would require a very simple method, whereas literate communities, in developed countries for example, would be able to use a format where they can self-administer the questionnaire. Similarly, the food list included in a DDQ would be very different between developing and developed countries.

Rather than using a 24 hour recall method as suggested in the guidelines (FAO, 2011) the development of a specific DDQ would mean participants could self-administer the DDQ (depending on literacy levels) by simply ticking yes or no to each food item. Also, researchers' time does not need to be spent categorising food items for each participant as food items will already be grouped into corresponding food groups in the DDQ.

2.3.2 Components and approach

A DDQ that can be self-administered by participants should to be easy to use and understand. It should be relatively short in length so that it can be completed in a short amount of time. To be able to assess nutrient adequacy, a DDQ needs to include all relevant food items and food groups consumed regularly by the population group being assessed. The dietary diversity data received from other dietary assessment methods is a list of food which is coded into

appropriate food groups. The FAO guidelines recommend that once a list of foods consumed is created, the researcher assigns a one to food groups consumed and a two to food groups not consumed (FAO, 2011). Where respondents complete a DDQ on their own, a simple list of foods would need to be developed to ensure it is easy to understand and does not require high literacy skills. Once completed, the number of food items and food groups (dietary diversity measures) could be counted very easily.

2.3.3 Food lists

In order to do an in-depth assessment of dietary diversity, an appropriate list of individual food items would need to be developed and an optimal level of aggregation of food groups would need to be determined (Ruel, 2003). The FAO suggest that one of the steps that need to be taken prior to dietary diversity data collection is meetings to refine food lists with key informants, such as community leaders and women in charge of food preparation of a household (FAO, 2011). This is important for reviewing food that is locally and seasonally available, cultural foods consumed, foods eaten by specific age groups, nutrient content of local food, common frequency of food intake and amounts consumed, what the common local dishes are and any local meal customs and terminology.

As there is limited information on how to prepare food lists for DDQ development, methods to create food lists for FFQs are useful. Willet (1998) suggests three methods for compilation of a food list for FFQs. The first suggestion is to examine published food composition tables and then select foods that contain the nutrients that are of interest to the study. The second approach suggested is to create an extensive list containing foods that are likely to be of interest, and methodically work through the list to decrease the list. Pilot studies of the food list should be carried out to aid reduction of the list. Thirdly, open-ended data, e.g. from 24-hour recalls or diet records, could be used to provide knowledge on foods that contribute to intake of nutrients of interest.

The development of food lists for DDQs requires discussion of key technical issues prior to data collection (FAO, 2011). Firstly, the minimum quantities of food required for food to be included in the questionnaire need to be decided upon. Dietary diversity is more strongly related to micronutrient adequacy when small food quantities of 15g or less are not included in the DDS (Arimond *et al.*, 2010). An example of this is a small amount of herbs being added to a dish being excluded. A study in Mali included condiments in their FVS counts, and hence if FVS was used alone as an indicator of dietary diversity it would give a more positive impression of dietary quality than there actually was (Hatloy *et al.*, 1998). Secondly, food items that can be

categorised into one or more food groups will need to be classified into one food group which is deemed the most appropriate. A hot pepper, for example, could be classified as a "vegetable" or as a "spices and condiments". It is important to consider this in the context of the focus population (FAO, 2011). Lastly, how mixed dishes (e.g. a casserole) should be recorded needs to be considered, as it is important that all of the individual components of a dish are recorded. Basic foods should be listed under their main ingredient, and commonly consumed and cultural dishes of the population being assessed should be identified (FAO, 2011). It is also suggested that probing for consumption of and recording of these commonly consumed mixed dishes should be practised to investigate which ingredients are usually recalled and those which are not recalled (e.g. as added fats or oils used in preparation of the mixed dish may not be recalled when asked about ingredients of the dish). Similar issues have been noted in development of food frequency questionnaires (FFQs), with previous research using coding systems that mean mixed foods and dishes are counted as food items, rather than individual components of the food/dish (Willet, 1998). This approach could be adopted for a DDQ in order to provide a smaller and more manageable list of foods and food groups.

The food groups also need to be considered in DDQ development. The selection of food groups for a DDQ should be driven by the purpose of the dietary diversity indices (Ruel, 2003). There is a consensus on how to classify foods into appropriate nutritious food groups in developing countries (FAO, 2011; Steyn *et al.*, 2006), but not in developed countries where discretionary food items and food groups are highly available. A standard list of food groups may not cover the great variations in dietary patterns between different cultures and population groups. Arimond *et al.* (2010) investigated the potential of dietary diversity indicators with variations in the number of food groups, and their ability to measure micronutrient adequacy. Eight food group diversity indicators (FGIs) were created to determine which level of aggregation of foods into food groups, and which minimum quantity of foods to be included in the score, to identify the best measure of micronutrient adequacy. It was evident from their results that it is best not to include foods that are eaten in trivial amounts and better performance (ability to measure micronutrient adequacy) was achieved with greater disaggregation of food groups. Development of a new DDQ should therefore not include foods eaten in small amounts (less than 15g), and should include a greater number of food groups.

Animal-derived foods play an important role in the diet. Foods derived from animals might be grouped into just one food group when assessing dietary diversity. The result of this is that it would only contribute one point to the DDS. Many studies have divided animal foods into two

or more categories in order to account for the benefits of including these foods in the diet. For example, some studies have separated dairy products from meat, fish and poultry; some have separated meat from fish, and some have put eggs in a separate category. A study based in West Africa used a total of eight food groups in their study, four of which were animal product groups – eggs, meat, milk and fish (Hatloy *et al.*, 1998). In contrast, in a Vietnamese-based study, only three of the 12 food groups were animal product groups – meat/poultry, fish/shellfish and eggs (Ogle *et al.*, 2001). The different emphasis on the animal product groups makes it difficult to compare the results of these studies, and this is something needs to be considered in development of a DDQ. See table 2.5 for the number of food items, food groups, animal food groups, and fruit and vegetables food groups included in previous dietary diversity studies in developing countries. Some studies have not made these numbers available, therefore this table only includes studies with available numbers.

It has been suggested that a vitamin A-rich food group be created which contains individual foods that contain 120 retinol equivalents (RE) per 100g (FAO, 2011). Vitamin C-rich food groups have also been used in dietary diversity investigation (Arimond *et al.*, 2010). Hatloy *et al.* (1998) used three fruit and vegetable food groups, which were vegetables, fruits and green leaves. Steyn *et al.* (2006) also used three fruit and vegetable foods groups: vitamin-A-rich fruits and vegetables; other vegetables; and other fruits. Including such food groups needs to be considered in DDQ development.

Table 2.5 – Number of food items and food groups used in previous dietary diversity research in developing countries

Research article	**Number of food groups used (DDS)**	**Number of animal food groups**	**Number of fruit and vegetable groups**	**Number of individual foods used (FVS)**
Hatloy *et al.* (1998)	8	4	3	75
Oldewage-Theron and Kruger (2011)	9	3	3	60
Steyn *et al.* (2006)	9	3	3	45
Mirmiran *et al.* (2006)	5 groups, 23 subgroups	7 subgroups	9 subgroups	Not calculated
Torheim *et al.* (2004)	10	4	3	76
Ogle *et al.* (2001)	12[1]	3	3	120
Fujita *et al.* (2012)	10	3	3	Not calculated
Mirmiran *et al.* (2006)	5 groups, 23 subgroups	7 subgroups	9 subgroups	Not calculated
Jayawardena *et al.* (2013)	12[1]	3	3	No maximum

[1]Total number of food group in analysis included discretionary food group(s)

It has been recommended in the FAO guidelines for dietary diversity measurement that nine nutritious food groups are included in the measurement of individual dietary diversity, which includes three fruit and vegetables groups, four animal-based food groups, as well as the groups starchy staples; and legumes, nuts and seeds.

2.4 Validation

2.4.1 Validity

Validity is the ability of a tool or method to measure what it was planned to measure (Block & Hartman, 1989; Lee & Nieman, 2003; Sawaya *et al.*, 1996). It is not an absolute value, rather an indication of whether a test score or proposed measure is relative to the area being studied (Kaplan, Bush, & Berry, 1976). If the findings in a study accurately represent the true circumstance or situation, then the study is considered to be valid (Biro *et al.*, 2002).

There are different forms of validity: relative, content and construct (Dobbin *et al.*, 1966; Kaplan *et al.*, 1976; Messick, 1990). Relative or criterion validity is assessed by comparing test scores with external variables which are known to accurately measure the phenomenon or characteristic of interest. There are two types of relative validity, predictive and concurrent. Concurrent validity is when the test score or proposed measure matches a criterion (standard or benchmark) simultaneously, whereas predictive validity is when the proposed measure or test score forecasts a criterion value on a future level. Both types of relative validity are based on the extent to which test scores and criterion scores are correlated. This correlation then forms the basis on which test scores are used to estimate an individual's status on a criterion or measure of interest.

Content validity is assessed by investigating the degree or ability of an instrument to adequately represent the situation or subject, and construct validity is assessed by investigating what qualities a test score or proposed measure actually measure through explanatory concepts and theories (Dobbin *et al.*, 1966; Kaplan *et al.*, 1976; Messick, 1990).

To ensure confidence in a measure, score or tool, the validity of this measure, score or tool should be determined. Although relative validity is often impractical to assess (Field, 2013), it can be assessed on dietary assessment methods (Gibson, 2005).

2.4.2 Key considerations in relative validity studies

There are key factors to consider in the design of relative validity studies. The participants in the study should be representative of the population under examination, with certain

characteristics of participants influencing responses to a reference method (Gibson, 2005). For instance, people who volunteer for validation research give more accurate responses (Riboli *et al.*, 1997). Moreover, men and women respond different to dietary assessment methods (Johnson, Goran, & Poehlman, 1994), and hence relative validity research should be tested on men and women separately (Gibson, 2005).

Another important factor is that the test and reference dietary assessment methods need to have the same objectives and measure the same factors over the same time period (Gibson, 2005). If test and reference methods do not cover the same time frame, then they are not covering the same food intake. It can be difficult to measure the relative validity of a method that is meant to measure usual or past dietary intake. Alternatively, current diet validation studies have been used to represent past diet, based on the assumption that current diet is the same as diet in the past. However, recalling diet in the past may actually be affected by recent food intake patterns (Rohan & Potter, 1984).

There also needs to be consideration of the order and spacing of the test and reference methods in validation studies. The test method should be conducted before the reference method in order to imitate the proposed study. Willet (1998) conducted a FFQ validation study, and the FFQ was administered before and after the reference dietary method, food records. It was carried out this way because there was concern the food recording process would alter awareness of intake and consequently alter completion of the FFQ in a way that artificially improved the questionnaires accuracy. The test and reference methods should be spaced to avoid influencing the response to the reference method (Gibson, 2005). If the time period between the two methods is too long, seasonal effects may be introduced, as food intake changes with changes in season. Days of the week should also be considered. It is recommended that all days of the week be covered to account for changes in diet patterns that happen across the week (Gibson, 2005).

Food records and repeated 24-hour recalls can be conducted over consecutive or interval days. A dietary variety score (DVS; similar to DDS) was calculated for children in a developed country. In this study the ability of three 24-hour dietary recalls to measure DVS as well as 15 consecutive days of dietary recall was assessed (Falciglia *et al.*, 2009). Three days were able to estimate DVS over 15 days, however three interval days of dietary intake were able to predict intake more precisely than three consecutive days. The spacing of the reference method should be considered in validation studies.

2.4.3 Validation of dietary assessment methods

In terms of dietary assessment methods, validity is the degree to which a method is able to measure the aspects of diet it was designed to measure (Willet, 1998). If dietary assessment methods do not measure diet accurately, then they may lead to false relationships between diet and health and/or disease bring reported (Cade, Burley, Warm, Thompson, & Margetts, 2004). Validation of a dietary assessment method involves comparison of dietary intake estimates with usual dietary intake. As discussed earlier, no dietary assessment method is free of error and it is difficult. if not impossible, to know an individual's true dietary intake (Lee & Nieman, 2003). There are procedures which attempt to measure the absolute validity of diets, however these are time-consuming, incredibly unpractical and cannot be guaranteed to reflect true food intake (Block & Hartman, 1989; Gibson, 2005). Absolute validity is only determined in studies that have limited subject numbers or cover short time periods only.

To reinforce, relative validity is whether a method measures what it is said to measure through comparison of the method to objective criteria (Field, 2013). Relative validity of dietary methods is the comparison of the "test" or newly developed method with a "reference" dietary assessment method. The reference method is termed so because it has previously demonstrated validity and hence is superior to the test method (Block & Hartman, 1989; Gibson, 2005; Sawaya *et al.*, 1996). For example, Beck *et al.* (2012) used a four-day weighed food record ("reference" dietary assessment method) to investigate the validity of an iron FFQ ("test" dietary assessment method).

The relative validity of a test dietary assessment method is indicated by the degree of similarity between the data provided between the test and reference methods (Gibson, 2005). Statistical analysis is conducted to measure this degree of similarity between the test and reference methods. A lack of consensus on which statistical methods to use on dietary assessment validation studies has been reported (Burema, van Staveren, & Feunekes, 1995). Statistical methods should be based on the study objectives, a range of statistical methods should be used, and nutrients of interest should be analysed separately (Gibson, 2005).

Assessment of relative validity can be done by tests on means or medians (Gibson, 2005; Nelson, 1997), such as paired t tests. If significant differences exist between means or medians of the test and reference methods, then bias may be present in the test method. Correlation analysis is also a commonly used statistical method in validation studies, such as Pearson correlation coefficients and Spearman rank correlation coefficients. Correlation analysis evaluates the strength of the relationship between test and reference methods at the

individual level (Gibson, 2005; Nelson, 1997). There are limitations to correlation analysis, including an exaggeration of the measure of agreement between the test and reference method, it does not measure the degree of agreement, and it cannot account for characteristics of the study population (Bland & Altman, 1986). Regression analysis is another statistical method for assessment of validity. It is considered an extension of correlation analysis and is commonly used when biomarkers are used as a validation technique (Gibson, 2005; Nelson, 1997). Regression analysis involves formulation of mathematical models to predict or validate a dependent variable (such as total protein intake) from an independent variable (such as urinary nitrogen excretion) (Nelson, 1997). Another method is cross-classification. In validation studies, participants are often categorised into groups based on intake from a combination of the test and reference method. From this, the percentage of participants who are correctly categorised is calculated, providing the extent of agreement between test and reference methods and hence gives indication of the test method's relative validity (Gibson, 2005; Nelson, 1997). Unfortunately, the percentage agreement calculated includes agreement that has occurred by chance, but this can be overcome by using weighted kappa statistic, a statistical measure used to adjust for this chance (Cohen, 1968). Additionally, the Bland and Altman approach can be used to statistically assess validity. This is where the mean and standard deviation of the difference between the test method and reference method for nutrients are calculated (Bland & Altman, 1986; Gibson, 2005). With this approach, results for a nutrient of interest from the test and reference methods should be plotted to assess for any outliers and bias. Another plot should then be drawn to show mean intake of a nutrient from test and reference methods together, against the difference of mean nutrient intake from test and reference methods. This will show whether the test and reference methods are interchangeable in relation to assessment of that nutrient.

Selection of a reference dietary assessment method is of great importance when testing relative validity of a new or test dietary assessment method. Depending on the test method, there are recommended combinations of test and reference dietary assessment methods which take into account the consideration of factors discussed in 2.4.2. For instance, if a single 24-hour recall is the test method, the appropriate reference method would be a single one-day weighed food record; if the test method was FFQ covering a 1 year period, the appropriate reference methods would be four, seven-day food records spaced evenly over a year period (Gibson, 2005). It must be noted, however, that for having an appropriate combination of test and reference methods does not necessarily mean that there will be good agreement between the two methods. It may instead indicate that the methods have the same or similar errors,

and this highlights the need to interpret dietary data in validation studies carefully (Gibson, 2005).

The test dietary assessment method can also be compared to biomarkers as a reference method. Biomarkers are external variables, generally components of the body which are able to reflect intake of one or more dietary components (Gibson, 2005). The main benefit of using biomarkers is that the errors that can occur with markers are different to those in questionnaires on intake, meaning the errors are independent (Kaaks, 1997). They provide a different approach to validation studies that compare a dietary assessment method with other dietary assessment methods, where similarity or agreement between methods may only be reflecting the same/similar errors in both methods (Gibson, 2005). For example comparing two methods that rely on memory may both have reporting errors present (Biro *et al.*, 2002). Moreover, some biomarkers have high sensitivity and provide a precise reference of dietary intake (Kaaks, 1997). For instance, 24-hour urinary nitrogen excretion strongly correlates with daily nitrogen ingested in the form of protein (Bingham & Cummings, 1985), and the doubly labelled water technique, which is the gold standard for measurement of energy expenditure, can reflect daily energy intake if subjects are in energy balance (Schoeller, 1988). However, the majority of biomarkers have low sensitivity, meaning they can only discriminate between very high and low dietary intakes (Gibson, 2005). They may not directly relate to intake due to factors such as nutrient absorption, tissue turnover, and sample collection and analysis (Cade, Thompson, Burley, & Warm, 2002), hence the importance of using another dietary assessment method for reference in validation studies.

Weighed food record are a common dietary assessment used as a reference method in validation of methods designed to assess omega 3 PUFA intakes, and the records ranged from three to 28 days in length (Overby, Serra-Majem, & Andersen, 2009). A study on the relative validity of an iron FFQ used a four day weighed food record as a reference method (Beck *et al.*, 2012). Weaknesses of using a food record as a reference method in this study were that the FFQ and the food records were both reliant on self-reporting, introducing a reporting bias, and the high day-to-day variation not being captured due to only a few recording days (Andersen *et al.*, 1999; Beck *et al.*, 2012). However, a benefit of using food records as a reference method for assessment of validity of a FFQ (or DDQ) is that they have been reported as independent of each other, meaning they both have different sources of error and hence will not be replicated from one method to the next. This would help avoid measures of validity that are spuriously high (Willet, 1998).

Weighed food records have often been labelled the “gold standard” for comparison with other dietary assessment methods for their validation (Gibson, 2005). A review on validation of FFQs found that weighed food records correlate better with FFQs than food recalls (Cade *et al.*, 2002). This implies that food records are a more appropriate reference tool than food recalls for validation of FFQs. Food records can be estimated or weighed. Weighed food records are favoured over estimated food records in locations where scales are a common kitchen/household utensil and ingredients in recipes are often recorded with weights (Black, 2001).Weighed food records can be conducted over consecutive days, or spread over interval days, and a spread of weekend and weekdays should be included to cover any changes in dietary habits (Gibson, 2005).

2.4.4 Time frame for reference dietary assessment method

Careful consideration needs to be given to the length of the reference dietary assessment method. It is important to get a balance between getting accurate information on usual diet and participant burden. A longer reference period may be favourable to get a greater picture of usual intake, with some research showing that validity improves when the number of days of a reference method is increased (Potosky, Block, & Hartman, 1990). However, longer periods recording food intake becomes a burden to participants, and hence habitual dietary patterns may change due to this recording process (Gibson, 2005; Lee & Nieman, 2003). It has been suggested that a weighed food record should be limited to three-days to avoid burden on participants (Meyer, Swierk, & Russell, 2013). There is no consensus on whether or not this is a long enough time to measure usual dietary habits. Livingstone and Black (2003) found that when measuring habitual energy intake, better precision is achieved when a seven-day record is used, compared to one to three day records. However, participants do find that recording food intake for seven days has high burden and this may lead to errors. Other research shows that three days is in fact a long enough period to measure usual intake (Sullivan, Brown, Williams, & Meyer, 2008). This suggests that a longer reference period is not necessarily the recommended period to use, because although it may better reflect usual intake, over time the food recording becomes tiresome to participants and errors in recording dietary intake are made, or changes to diet patterns are made to make recording easier.

2.4.5 Validation of dietary diversity

It essential that validity of dietary diversity is assessed to ensure the dietary assessment method used is accurate. Similarly, with the increasing number of measures available to represent diet quality, there needs to be validation of these measures to identify their

strengths and weaknesses (Torheim *et al.*, 2003). There is a general process for validation in dietary diversity studies (Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011; Ruel, 2003; Steyn *et al.*, 2006). Firstly, measures of diet quality, nutrient adequacy ratio (NAR) and mean adequacy ratio (MAR), are calculated as estimates of the nutrient adequacy of diets. The inclusion of specific micronutrients in measures of nutrient adequacy needs to be decided upon, depending on the setting in which dietary diversity is being assessed. Secondly, these measures of nutrient adequacy are compared with dietary diversity scores, often DDS and FVS, to determine their ability to reflect nutrient adequacy, and hence diet quality. Lastly, the cut-off values of DDS and FVS are tested for sensitivity and specificity in their ability to predict diets with nutrient adequacy.

Previous dietary diversity validation studies have been conducted (Hatloy *et al.*, 1998; Mirmiran *et al.*, 2006; Mirmiran *et al.*, 2004; Steyn *et al.*, 2006; Torheim *et al.*, 2003). Oldewage-Theron and Kruger (2011) used a quantified FFQ (QFFQ) to measure dietary diversity, and administered a 24-hour recall as a reference dietary assessment method. The diversity scores, DDS and FVS, were constructed from the QFFQ and compared to validation scores, NAR and MAR, calculated from the 24-hour recall data to assess the degree of agreement between the methods. Steyn *et al.* (2006) on the other hand used 24-hour recall data as the test method, and a FFQ as the reference method. The selection of dietary assessment methods is these studies were chosen because the research was being conducted in illiterate and poor communities, where food records require literate participants (Biro *et al.*, 2002).

A study in Malawi on 77 children provides a useful example of dietary diversity validation. The FVS and DDS were determined from three day weighed food records and were then validated against nutrient adequacy scores which were also calculated from the weighed food records (Hatloy *et al.*, 1998). This validation technique using nutrient adequacy scores was developed by Madden and Yoder (1972), and since then, has been developed by others (Hatloy *et al.*, 1998; Ruel, 2003; Steyn *et al.*, 2006). One of the validation scores is nutrient adequacy ratio (NAR). This is the ratio of the actual intake of a single nutrient (determined from dietary assessment) and the estimated average requirement (EAR) of this nutrient. The EAR value (estimated to meet the needs of about 50% of the population) is used rather than the recommended daily intake (RDI) (estimated to meet the needs of about 97.5% of the population) value because the prevalence of inadequate intakes within a group is assessed (National Health and Medical Research Council, 2006). Conversely, RDI is recommended to be

used for individuals as usual intakes at or above this level has a low probability of inadequacy; therefore it should not be used for assessment of group intakes.

Mean adequacy ratio (MAR) is the sum of all NAR calculated, divided by the total number of nutrients used in the assessment. The MAR is calculated to quantify nutrient adequacy (Hatloy *et al.*, 1998). The theory behind this technique is that if recommended intakes are being met, NAR and MAR values will be closer to one and higher values will indicate a diet adequate in nutrients. The relationship between these nutrient adequacy measures and dietary diversity measures is explored to determine whether the method used to assess dietary diversity is valid, and whether the dietary diversity measures can also reflect dietary quality. Through this validation technique, dietary diversity measures have been shown to provide a moderately good assessment method for evaluating nutritional adequacy of diets, as seen by significant associations between MAR and FVS and DDS (Hatloy *et al.*, 1998). Table 2.6 gives an overview of validation scores used commonly used in previous dietary diversity research.

Table 2.6 – Scores used to validate measures of dietary diversity

Indicator	Purpose	Calculation of indicator
NAR – nutrient adequacy ratio	Indicate whether nutrient intakes meet the estimated average requirement for that nutrient (1 or 100% indicates adequate nutrient intake)	$\frac{daily\ nutrient\ intake}{recommended\ nutrient\ intake}$
MAR – mean adequacy ratio	Indicator of micronutrient adequacy (1 or 100% indicates intake of all nutrients as adequate)	$\frac{Sum\ of\ NARs\ (each\ truncated\ at\ 1)}{number\ of\ nutrients\ evaluated}$

As mentioned, Oldewage-Theron and Kruger (2011) investigated dietary diversity using a QFFQ, and used a 24 hour recall as a reference dietary assessment method. The dietary diversity scores in this study were determined from the seven-day QFFQ, and the validation scores were gathered from the 24-hour recall. Nutrient adequacy ratios were calculated for energy, protein, carbohydrates and 21 micronutrients. For each nutrient, the actual daily intake consumed by participants was divided by the South African recommended dietary intakes for the women's age category. The NARs where then averaged to create a MAR, which was used to evaluate adequacy of the diets. The relationship between DDS and FVS and adequacy ratios was explored through Pearson Correlation analysis. Using these validation

techniques they were able to conclude that FVS and DDS were acceptable indicators of dietary adequacy and hence diet quality (Oldewage-Theron & Kruger, 2011)

The estimated average requirements (EARs) have been used as the values for recommended intake in calculation of NARs (Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011). Using EAR instead of other nutrient reference values is beneficial, as it has been designed to account for within-subject variation of nutrient intakes, therefore its use can be applied to a group and avoid over-estimation of intakes (Gibson, 2005). Where EAR was not available, the adequate intake (AIs) were used (Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011). The AI is the nutrient reference value suggested for use when an EAR is not available, and this can also be applied to groups (Gibson, 2005). The NARs should be truncated at one so that when averaged to give MAR, they will be able to serve as an indication of overall diet quality, with a value of one indicating that dietary intake is meeting requirements (Steyn *et al.*, 2006). If the NAR is not truncated, then high intake levels of a nutrient would compensate for low levels of nutrients consumed (Ruel, 2003). In some dietary diversity research, the NAR for nutrients which were adequately consumed by all participants (NAR of one for all participants) have not been included in the calculation of the MAR (Hatloy *et al.*, 1998). Energy and protein have also been excluded from the MAR calculation in some research (Steyn *et al.*, 2006), and have been left in MAR calculation in others (Torheim *et al.*, 2003).

The NAR is calculated using published nutrient recommendations for a number of nutrients, and the nutrients need to be decided upon when validating scores of dietary diversity. See table 2.7 for nutrients used in previous dietary diversity validation studies. The nutrients for which NAR is commonly calculated are protein, vitamin A, vitamin C, thiamine, riboflavin, iron and calcium. Previous dietary diversity studies in developing countries have put more emphasis on foods and nutrients that are insufficient in the diets of the populations being assessed. For example, animal foods are a major source of nutrients, but in Africa these foods are not consumed in sufficient quantities. Micronutrient deficiencies are a major problem in Africa, specifically iron, vitamin A, iodine, folate and zinc (Steyn & Ocshe, 2013). Therefore, these nutrients are often included in NAR and MAR calculations. A dietary diversity study in Kenya placed strong emphasis on vitamin A, measuring serum retinol concentration and including a specific vitamin A-fruit and vegetable food group in their DDS (Fujita *et al.*, 2012). A South African study also included a specific vitamin A-fruit and vegetable food group in the measurement of dietary diversity (Oldewage-Theron & Kruger, 2011). Also, energy deficiency is a problem in Mali (Africa), therefore Torheim *et al.* (2003) put emphasis on animal foods and

oil/sugar groups and the nutrients obtained from these foods. The fats and oils food group have been found to not contribute to the micronutrient density of diets, however it does contribute to energy intake as well as aid absorption of carotenoids from plant sources and the fat-soluble vitamins (FAO, 2011), which provides evidence for its inclusion in dietary diversity research.

The number of nutrients investigated in dietary diversity research has varied, for example Oldewage-Theron and Kruger (2011) examined a total of 24 micronutrients, whereas (Torheim *et al.*, 2003) investigated only 10 micronutrients. Using a greater number of nutrients in the NAR calculation will provide a greater overview of diet, as diet quality is not limited to just one or a few nutrients or just macronutrients compared to micronutrients. It relates back to the guideline statements around dietary variety – by eating a greater variety of foods and food groups, a wider range nutrients should be consumed which can consequently improve health (Jansen *et al.*, 2004; Labadarios *et al.*, 2011; Michels & Wolk, 2002; Ministry of Health, 2003a; Ruel, 2003). Therefore, a MAR value which is the average of all the NARs will be more likely to represent nutrient adequacy if it includes a greater number of nutrients in its calculation.

Table 2.7 – Nutrients selected for NAR calculation in previous dietary diversity research

Nutrient for which NAR was calculated																	
	Macronutrients				Micronutrients												
Research article	**Energy**	**Protein**	**Carboh-ydrate**	**Fat**	**Zinc**	**Vitamin A**	**Vitamin C**	**Thiamine**	**Riboflavin**	**Niacin**	**Folate**	**Vitamin B6**	**Vitamin B12**	**Iron**	**Calcium**	**Other**	**Total number of nutrients used**
Hatloy *et al.* (1998)		✓	✓		✓	✓	✓	✓	✓	✓	✓			✓	✓		11
Oldewage-Theron and Kruger (2011)	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Cholesterol, magnesium, copper, chromium, selenium, iodine, pantothen-ate, biotin, vitamin D, vitamin E	24
Steyn *et al.* (2006)	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		14
Mirmiran *et al.* (2006)	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓	Phosphorous, magnesium, potassium	13
Torheim *et al.* (2003)	✓	✓		✓		✓	✓	✓	✓	✓				✓	✓		10
Mirmiran *et al.* (2004)	✓	✓		✓	✓	✓	✓	✓	✓					✓	✓	Phosphorous, magnesium, potassium	13
Total out of 6 research papers	5	6	2	4	5	6	6	6	6	4	3	2	2	6	6		

Dietary diversity measures need to have cut-off values in order to indicate whether diets have high or low diversity, and whether they are nutritionally adequate or not (Hatloy *et al.*, 1998). International cut-offs are meaningless due to the variation in intake between countries. Instead, cut-offs need to be defined in the context that they are used (Ruel, 2003). When selecting cut-offs that represent nutrient adequacy it is important to use the sensitivity-specificity analysis developed by Hatloy *et al.* (1998).

Sensitivity is the ability of an index to reflect nutritional status, and specificity is the extent to which an index can identify individuals that are genuinely well nourished (Gibson, 2005). An index that has 100% sensitivity is able to identify all individuals who are malnourished, and there will be no false negatives – people who are actually malnourished get classified as well nourished. An index with 100% specificity can identify all well-nourished individuals correctly, and there will be no false positives – people who are well-nourished and get classified as malnourished. Sensitivity and specificity are both affected by cut-off points (Gibson, 2005). For example, increasing a cut-off value may increase sensitivity, but consequently this will decrease specificity, and vice versa. An ideal situation is to have both low false positives and low false negatives, meaning the index is able to correctly classify individuals who are well nourished from those who are malnourished.

In terms of sensitivity and specificity of cut-off points used in dietary diversity research, a range of DDS and FVS cut-off points need to be assessed to find the levels that give high sensitivity, but still maintain specificity. To do this, the range of cut-off points for FVS and DDS need to be tested against MAR, with MAR being the gold standard for assessing nutrient adequacy (Hatloy *et al.*, 1998). An example of the sensitivity-specificity analysis is in an African dietary diversity study. The sensitivity of FVS and DDS was tested against nutritional adequacy, which was defined as an MAR value of 0.7, in order to determine an appropriate FVS and DDS cut-offs. To reach nutrient adequacy (MAR of 0.7) and have highest sensitivity and specificity possible, the FVS cut-off was five individual food items (Oldewage-Theron & Kruger, 2011). If the cut-off was lower than five, the sensitivity would drop too much, meaning those who did not have nutrient adequacy were classed as having nutrient adequacy. If the cut-off was higher than five, the specificity would drop too much, meaning those who had a nutrient adequacy were classed as having a nutritionally inadequate diet. Similarly, DDS was most specific and sensitive at assessing nutrient adequacy when the cut-off was four food groups (Oldewage-Theron & Kruger, 2011).

Other research found that if a MAR of 0.50 is selected to represent nutrient adequacy, then a DDS cut-off of four, and a FVS cut-off of six are the most appropriate indicators of MAR and nutrient adequacy because they give the highest percentage values for sensitivity and specificity (Steyn *et al.*,

2006). The cut-off values selected will depend on the number of food groups and individual foods made available to the participants to select in the DDQ.

The analysis of sensitivity-specificity of dietary diversity cut-off values has been conducted in developing countries, where dietary diversity is poor (Oldewage-Theron & Kruger, 2011; Ruel, 2003). Where dietary diversity is high in developed countries (Falciglia *et al.*, 2009; Foote *et al.*, 2004), the ability to conduct analysis of sensitivity-specificity of dietary diversity cut-off values to predict nutrient adequacy is unknown. If the intake of micronutrients is adequate at all levels of food items and food group consumed, then a cut-off would not be able to be determined.

2.5 Summary

The ability of dietary diversity to reflect micronutrient adequacy of individuals has been proven in developing countries. There is lack of consensus on dietary diversity measurement and how to assess the relative validity of dietary diversity measures to reflect micronutrient adequacy in a developed country setting. A DDQ is a quick and easy dietary assessment method which could be used to assess dietary diversity and hence diet quality. However, it would need to be adapted to incorporate differences in setting and the characteristics of the population group, such as ethnicity, culture and literacy levels, in which dietary diversity is being assessed.

3. Methods

3.1 Study Design

Measurement of dietary diversity has previously been used in the developing country setting to reflect nutrient adequacy (FAO, 2011). This thesis was designed as a cross-sectional study, using a subsample of women from the Women's Examining Predictors Linking Obesity Related Elements (EXPLORE) Study to complete a newly developed DDQ, a dietary assessment tool which measures dietary diversity. Participants also completed weighed four-day food records as a reference dietary assessment method to validate the DDQ. The Women's EXPLORE Study aimed to investigate how different body weight and body fat profiles are linked to chronic disease in women.

3.2 Ethical Approval

Ethical approval for this research was obtained from the Massey University Human Ethics Committee (MUHEC): Southern A, Application 13/13. All participants gave written informed consent to participate in the Women's EXPLORE Study.

3.3 Study Population

3.3.1 Eligibility

To be included in the Women's EXPLORE Study, participants needed to be female and either of Māori, Pacific or New Zealand European ethnicity. It was also required that they were pre-menopausal and post-menarche (for at least one year), and be non-pregnant and non-lactating. They also needed to be healthy with no chronic diseases. The age range for the study was 16-45 years.

3.3.2 Sample size

For validation of dietary assessment methods, a sample size of more than 100 participants is recommended (Serra-Majem *et al.*, 2009; Willet, 1998). Previous dietary diversity research has been conducted on sample sizes as small as 77 participants (Hatloy *et al.*, 1998), and as large as 2200 participants (Steyn *et al.*, 2006). With time constraints in place, the aim was to use the first 105 participants of the Women's EXPLORE study.

3.4 Research Tools

3.4.1 DDQ development

The first step in the development of the dietary diversity questionnaire (DDQ) was to conduct an investigation on previous dietary diversity research and methods used to assess dietary diversity. Decisions were then made on the DDQ format and individual food items and food groups to be

included in the DDQ. The DDQ was tested twice in pilot studies prior to being completed by participants in the Women's EXPLORE Study. The Guidelines for Measuring Household and Individual Dietary Diversity by the Food and Agricultural Organisation (FAO, 2011) and a dietary diversity measurement tool created by Food and Nutrition Technical Assistance (FANTA) (Swindale & Bilinsky, 2006) were used to guide the DDQ development. These documents provided ideas around DDQ development, including technical issues that should be discussed prior to data collection, as well as instruction for administration of the questionnaire.

DDQ - Format

A DDQ had been created for use on a South African population (Matla, 2008), and the format of this DDQ was used as a starting point for the DDQ development in this study. The DDQ format was simple, with a list of foods grouped into their relevant food groups and two columns headed yes and no. Completion of the questionnaire involves an individual or researcher going through the food list, and each food item gets one tick in either the yes or no column depending on whether or not the food was consumed in the specified reference period.

DDQ - Food list

A draft DDQ was created containing potential food groups and an extensive list of food items that are potentially eaten by women living in New Zealand. A background search on diets of Māori, Pacific or NZ European women living in New Zealand was conducted to provide relevant food items to include in the food list. The New Zealand food composition tables (Sivakumaran, Huffman, & Sivakumaran, 2013) and National Nutrition Survey results (Ministry of Health, 2012) were used to identify foods commonly consumed by the study population group. Web searches on Māori and Pacific Island traditional foods also provided insight into cultural foods that should be included in the questionnaire. Discussions with family, friends and colleagues of all ethnicities also provided insight into foods eaten by women in New Zealand.

There is minimal research on dietary diversity in developed countries compared with developing countries; hence there was a strong focus on how to include food groups in the DDQ that reflected intake in a developed country, e.g. greater intake of snack and takeaway foods. In spite of the guidelines in place for healthy eating for adult New Zealanders (Ministry of Health, 2003a), the New Zealand population has low intakes of fruit and vegetables, high intakes of fat and sugar and rising obesity rates (Ministry of Health, 2012). Previous research on dietary diversity was focused toward nutritious food items and food groups only and whether energy and nutrient intakes are met. This was also the focus for this study, but to complement this there was also an investigation of the consumption of discretionary food items and food groups, as these foods also contribute to energy

and nutrient intakes. Therefore, the DDQ also included food items and food groups that were not nutritious. Food items were considered discretionary if they were high in fat, sugar and sodium, and/or low in micronutrients, and/or pre-packaged, processed or sold in takeaway food outlets. The food groups suggested in the Guidelines for Measuring Household Dietary Diversity were also used to consider whether food items should be nutritious or discretionary (FAO, 2011).

DDQ - Pilot studies

A paper copy of the DDQ was piloted on students undertaking post-graduate nutrition studies and second and third year undergraduate nutrition students in Palmerston North and Auckland (majority females and within the age range 16 - 45 years). The pilot study was conducted to find any missing foods, assess understanding of the foods included, and to assess understanding of the instructions to complete the questionnaire. General feedback obtained from the pilot study was that the women found the questionnaire straightforward to fill out and that is was relatively quick to complete. Foods that women included in the other food items sections were: un-salted peanut butter, gluten-free cake, rice milk, tofu, kale, cranberries, liquorice, ginger, gnocchi, almond milk, and Jerusalem artichoke. From this changes made to the DDQ were addition of artichoke to the vegetable food group, changing "soy milk" to "other milks (e.g. soy milk, rice milk, almond milk, etc.)", and addition of "tofu, tempeh" to the legumes and nuts food group. The remaining foods were all considered, but all fell under other foods already in the DDQ, therefore no alterations were made to the DDQ based on these foods. This did highlight however that it needs to be made clearer to participants that foods or food products in different forms need to be considered, e.g. gluten-free cake would still go under cakes, and unsalted peanut butter would go under peanut butter. The instruction blurb at the top of the DDQ originally said

"*Please tick the foods you consumed during the past 7 days. You only need to tick a food once even if it was consumed several times."*

Following the pilot studies, the instruction blurb was amended to include the following:

"*For foods that require preparation (e.g. meat) consider all types of preparation and cooking methods. Also consider foods that can be eaten in fresh, frozen, dried or canned versions."*

The DDQ was uploaded onto an online survey software system (Survey Monkey). It was piloted a second time using the online format by post-graduate nutrition and dietetic students (again majority females and within 16-45 years). There were no other food suggestions that were raised from this second pilot, nor were there any difficulties understanding of the foods included and the instructions to complete the questionnaire.

DDQ - Decisions and assumptions

Important decisions and assumptions that were made during the DDQ development process are included in table 3.1. Adjustment of the food list and aggregation of food groups was continued until researchers were convinced that all suitable food groups and individual foods relevant to the study population group were included in the DDQ. It was decided that the DDQ for participants to complete would include a total of 14 food groups, and 237 individual foods. See Appendix A for the final DDQ used.

Table 3.1 - Decisions and assumptions made during DDQ development

Topic	**Decisions and Assumptions**
Creating a DDQ relevant to a developed country	- The main purpose was to develop and validate a DDQ for a population group in a developed country. Diets in developing countries consist mainly of starchy staples (Ruel, 2003), and individual food variety may be as low as three foods (Oldewage-Theron & Kruger, 2011). - In a developing country this may not be the case. Therefore, the DDQ incorporated food groups in a way that portrayed diets of developed countries rather than developing countries. In previous dietary diversity studies only nutritious food items and food groups are included (Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011). Within the DDQ there was inclusion of nutritious and discretionary food items and groups. An example of discretionary foods being included was the inclusion of muesli bars and sweetened cereals in the foods group "breads, cereals, starchy vegetables". There was a group dedicated to fats and oils due to high saturated fat intake of New Zealanders, and a "drinks" group due to high frequency of juice, soft drinks and energy drinks (Ministry of Health and Otago of University 2011). There were also food groups for alcohol, sauces, spreads and flavourings, sweet snacks, savoury snacks, and takeaway and fast-foods in the DDQ.
Assessment period	- The time period that dietary diversity is assessed has ranged from one to 15 days (Drewnowski *et al.*, 1997). - The period of time for this DDQ was the previous seven days to cover both week and weekend days.

Topic	Decisions and Assumptions
Number of food items and food groups	- 14 food groups were included in the DDQ: 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 flavourings; sweet snacks; savoury snacks; and takeaways and fast-food. - Previous research showed that dietary diversity indicators have better precision when there was greater disaggregation of food groups (Arimond *et al.*, 2010), hence a high number of food groups was used – In other dietary diversity research, Steyn *et al.* (2006) used nine food groups, Torheim *et al.* (2004) used 10 food groups, and Hatloy *et al.* (1998) used eight food groups. - 237 individual food items were included in the DDQ. Previous research on dietary diversity have used 75, 40 and 45 nutritious food items (Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011; Steyn *et al.*, 2006). One study that included discretionary food items used >120 food items (Ogle *et al.*, 2001). - Number of food items and food groups in the final analysis:16 nutritious food groups, with 143 nutritious food items; and nine discretionary food groups, with 94 discretionary food items.
Order of food groups	- The nutritious food groups were listed first, followed by the non-nutritious foods groups. Dissimilar to the interviewer-based South African DDQ (Matla, 2008). Dissimilar to the South African DDQ, the headings “nutritious foods” and “non-nutritious foods” were not included in the actual questionnaire as the researchers decided it may affect how participants answered the questionnaire.
Disaggregation of food items	- Foods items were grouped based on their main ingredient. For example crackers were grouped into cereals (wheat or rice often being the main ingredients of crackers). - In a developed country there are foods that have been processed or altered to contain different nutrient content, such as the availability of a range of milks with varying fat content. For this reason, a range of milk and yoghurts types based on their fat content were listed separately in the DDQ. Similarly, white and whole-grain/wheat-meal/multi-grain breads were listed separately. - Raspberries, blueberries and boysenberries, and cherries were grouped

Topic	Decisions and Assumptions
	together based on the assumption that these are eaten in similar quantities and have similar nutrient content (Sivakumaran *et al.*, 2013). - Coffee was disaggregated into two food items: coffee, instant or brewed, with or without milk; and coffee-based drinks. - See questionnaire (Appendix A) to further see how foods were listed.
How can participants include food items that are not in the DDQ	- An "other" option was included at the end of each food group where participants could write foods that they consumed but may have been missed from the DDQ.
Foods eaten in small amounts	- It is recommended to avoid including foods eaten in trivial amounts for the purpose of dietary diversity indicators being able to assess micronutrient adequacy (Arimond *et al.*, 2010). An amount of 15g was suggested, for which foods consumed in amounts less than this should not be included. Also, whole foods or food products were included only, therefore food items such as artificial sweeteners, spices and baking products (e.g. baking soda), were not included in the DDQ. - Dips, sauces and spreads were included, with their contribution to total energy intake being similar to that of other food groups like egg and egg dishes, and pork (Ministry of Health and Otago of University 2011).
Foods that could be included in more than one category	- Chilli could be a spice or a vegetable. Spices were not included in the DDQ, therefore chilli was included in the vegetable food group. - Tomato is a fruit but was placed in the vegetable food group because it is eaten like a vegetable rather than a fruit.
Mixed dishes	- Mixed dishes, such as casserole and stir-fry were not included. Instead their individual components were to be selected by participants.
Incorporation of Māori foods	- Intake of traditional Māori foods and foods commonly consumed by Māori in more modern times were considered: kumara, roe, shellfish, rewena (Māori bread), doughboys, yams, puwha, watercress, mutton-bird, paua, eel (Best, 1902; Rush, Hsi, Ferguson, Williams, & Simmons, 2010). Considered food dishes such as boil-up, hangi (pit in which food is cooked on heated stones) (Te Taura Whiri i te Reo Māori, 2010) to ensure food items included in these dishes were included in the DDQ.
Incorporation of Pacific foods	- Inclusion of the following foods: taro, coconut milk, coconut cream, coconut flesh, fermented milk e.g. buttermilk, kava, koko, tinned meat e.g. corned

Topic	Decisions and Assumptions
	beef, hock and pork bones, green banana/plantain, papaya and mango. Considered food dishes such as palusami (taro leaves with coconut cream), taro/spinach leaves in coconut milk, lu pulu (taro leaves and corned beef), watercress and sesame seed salad) (Harrington & Meyer, 1994).
Inclusions of food examples	- It was decided to include some food examples to help participants complete the DDQ. Examples included brands of food commonly consumed, to help trigger a participant's memory of consuming that food. For instance, yeast spread may not mean anything to a participant, but when the example of "Marmite" is placed beside yeast spread, the participant is reminded that they did eat this food item.
Consideration of preparation and cooking methods	- Participants were requested at the start of the DDQ to consider preparation and cooking methods used to ensure inclusion of all foods eaten in the reference time period, for example to ensure oil and salt were ticked "yes" if used.
Foods that can be consumed in different forms	- Participants were requested to consider foods that can be eaten in fresh, frozen, dried or canned versions when completing DDQ. However, these would still only contribute one food item as they will be nutritionally similar.
Year-long study period and changes in seasons	- A range of seasonal foods were included in DDQ in order to account for changes in dietary intake that occurs with change in season (Gibson, 2005).

3.4.2 Food record as a reference method

In order to validate the newly developed DDQ, a weighed four-day food record was selected as the reference dietary assessment method. Weighed food records have been labelled the gold standard reference method when validating dietary assessment methods (Gibson, 2005), hence their use as the reference method for the DDQ validation.

Participants were allocated four days to conduct the food record. These were the four consecutive days following their visit to Massey University for testing, including at least one weekend day. A range of all days of the week were covered across all participants, as it important that all days of the week are covered and evenly represented in dietary assessment (Gibson, 2005).

3.5 Study Process

3.5.1 Overview of Women's EXPLORE Study process

The Women's EXPLORE study involved three phases. See figure 3.1 for the three phases of the Women's EXPLORE Study process. This was followed by the completion of a food record and the DDQ for this study.

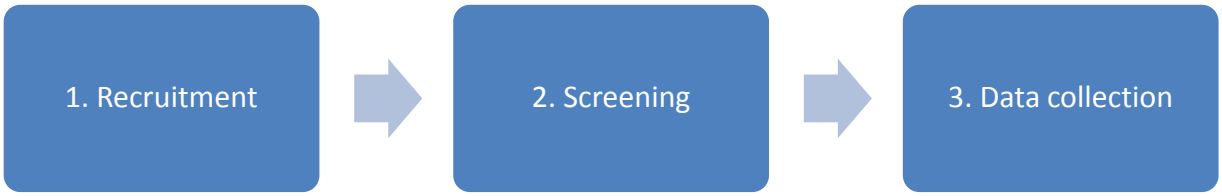


Figure 3.1 – The three study phases of the Women's EXPLORE Study

3.5.2 Recruitment

Recruitment of participants for the Women's EXPLORE Study commenced August 2013 and involved local recruitment using flyers at the university accommodation areas, recreation centre and the library. There was also advertisement in the Healthy Food Guide magazine, at nutrition symposiums, ProCare (a healthcare service in Auckland) and West Fono Health Trust (healthcare service for Pacific people). Members of the Women's EXPLORE Study team also travelled to schools, the Navy and events like the Pasifika Festival and YWCA (Young Women's Christian Association) fundraising event to recruit and screen participants. Recruitment for this study finished by May 2014, but recruitment continued for the Women's EXPLORE Study.

3.5.3 Screening

There were two parts to the screening phase. Firstly, women interested in participating in the study were directed to the Women's EXPLORE Study website to complete the eligibility questionnaire in paper format if they did not have internet access. The questionnaire included a health screen and questions on ethnicity to determine whether or not they were eligible for the study. If participants met these requirements for the study, then they would undergo the second phase of screening.

The second part of screening was to determine body composition. The Women's EXPLORE Study grouped participants based on their body composition, therefore screening included weight and body composition measurements using bioelectrical impedance analysis (BIA) and height measurements using a stadiometer. Participants were then age-matched across ethnic groups and split into one of the three body composition profile groups based on body fat percentage and BMI:

normal weight, hidden fat and overweight/obese. The body composition profile groups are not relevant for this study.

3.5.4 Data collection for Women's EXPLORE Study

Participants visited Massey University following eligibility assessment to undergo testing/data collection for the Women's EXPLORE Study. The women came in fasted for a two and a half hours period to complete the testing. Testing included blood sample collection, blood pressure (automated sphygmomanometer), body composition assessment (BodPod, DEXA scan), taste testing and questionnaires (FFQ, eating behaviour and eating habits).

3.5.5 DDQ

Participants with internet access were sent an email on the 6th day following testing to remind them to complete the DDQ the next day, with the online link to the Survey Monkey DDQ included in the email. Participants without internet access were given a paper copy of the DDQ when at Massey University, and an envelope to return it in. The DDQ was to be answered retrospectively by the participants, reflecting on their food intake over the previous seven days.

3.5.6 Food record

While at Massey University for testing, participants watched a video on how to complete a weighed food record, including instructions on details regarding food recording (e.g. type and cuts of meat, type of milk, cooking method, brand names, etc.) recommendations to not change from normal eating patterns, to include nutrition labels for fortified or uncommon foods, listing supplements used, attaching recipes, and explaining how to use the electronic scales. Participants were each given the weighed four-day food record to record their dietary intake and any recipes they used, see Appendix B. This also provided some written instructions on how to complete the food record. They were also given a portion guide pamphlet that they could use to estimate their food intake when not appropriate to use their scales, see Appendix C. This guide has a range of photos of different foods in varying portion sizes. Participants were also issued with electronic scales if they did not have their own and a box with a courier sticker attached to return the scales. Participants were allocated four days to complete the record, which was the four days following their visit to Massey University.

3.5.7 Standard operating procedures

Standard operating procedures (SOPs) were developed for the instructions to give to participants for completion of the DDQ and food records. This was to ensure consistency in instructions given by all members of the Women's EXPLORE Study team, as well as to ensure all important points were

covered so that participants felt confident to complete both dietary assessment methods adequately. See Appendix D and E for the SOPs for DDQ and food records, respectively.

Where DDQs and food records were not completed or returned by participants, a phone call was made and a text message sent to participants to encourage them to complete the DDQ and food records, and/or request they return the food record in the mail. Participants were excluded from the study if they did not complete both the DDQ and the food record.

3.6 Data Handling, Data Analysis and Statistical Analysis

3 6.1 Data handling

DDQ

The majority of the DDQs were completed online. Two DDQs were completed on paper as participants did not have internet or computer access, and were entered manually into the online DDQ. The DDQ data was downloaded from Survey Monkey into Microsoft Excel and thoroughly checked to ensure each participant had filled out the DDQ completely and that any double-ups where participants re-started the DDQ were removed.

Prior to data analysis, the DDQ food grouping was altered so that there was greater disaggregation of food groups. The food groups were disaggregated from 14 to 25 food groups. This was to allow a finer division between nutritious and discretionary foods groups. An example is the flesh food group, which was disaggregated into four food groups: meat; poultry; fish and seafood; and discretionary meat, poultry, fish and seafood. There were no new foods added and no foods were removed, only a shuffling of where individual foods were positioned. Therefore this does not alter the results in terms of what was collected from participants - participants would still have selected yes or no to all the same foods. This alteration of food groups was to allow a better understanding of nutritious and discretionary foods and food groups consumed by the participants. See table 3.2 for the alteration of food groups.

The cut-off for being included in the vitamin A-based group was ≥100ug total vitamin A equivalents per cup of food. The vitamin C-based food group was based on ≥30mg of ascorbic per cup of food. Values were based on the Concise NZ Food Composition Tables (Sivakumaran *et al.*, 2013), the USDA National Nutrient Database for Standard Reference (United States Department of Agriculture, 2014), and on food nutrient tables (Hands, 2000). If a fruit or vegetable had high vitamin A and vitamin C, vitamin A took precedence and the item was categorised into the vitamin-A rich group. A total of 16 nutritious and nine discretionary food groups were used. See Appendix F for the final list of food items within each food group.

Table 3.2 – Disaggregation of food groups from DDQ for analysis

Food groups in DDQ	Food groups in analysis
Flesh food groups	Meat Poultry Fish and seafood Discretionary meat, poultry, fish and seafood
Eggs	Eggs
Dairy products	Dairy products Cheese Discretionary dairy products
Breads, cereals and starchy vegetables	Breads Cereals Starchy vegetables Discretionary breads, cereals and starchy vegetables
Legumes and nuts	Legumes Nuts and seeds
Fruits	Vitamin A-rich fruits and vegetables Vitamin C-rich fruits and vegetables
Vegetables	Other fruits Other vegetables
Oils and fats	Oils and fats
Drinks	Drinks
Alcohol	Alcohol
Sauces, spreads and flavourings	Sauces, spreads and flavourings
Sweet snacks	Sweet snacks
Savoury snacks	Savoury snacks
Takeaways and fast-food	Takeaways and fast-food

Food records – Dietary diversity

As part of the validation process, dietary diversity measures were calculated from the food records. A Microsoft Excel spread sheet was set up to contain all the foods items and food groups that were included in the DDQ. The food records were manually entered onto this excel document. This data was to provide a count of food items and food groups consumed over a four day period based on the food records, which could then be compared to the scores calculated from the actual DDQ.

Again, a list of decisions and assumptions were made to ensure that the entry of food records into the dietary diversity excel document were consistent, see Appendix G.

Food records - Nutrients

As food records were returned to Massey University, they were checked to ensure they were completed to an adequate standard, that writing could be understood and that four full days of diet recording were included. Participants were contacted for clarification of their food record where necessary. The completed food records were electronically stored and used to enter manually into FoodWorks version 7 (Xyris Software, 2012). FoodWorks is a software programme that is used to

analyse diets, recipes and nutrients, providing average daily intakes of energy, macronutrients and micronutrients. The New Zealand – Diet and Recipe Analysis (abridged) database was selected for the food record entry into FoodWorks, as it is a complete dataset without any missing nutrient values.

Some assumptions and decisions had to be made when entering food records into FoodWorks. This was because some foods were not in the database, variation in cooking technique options available in the database, the alterations in weight of food after preparation/cooking, lack of data provided by participants, and to ensure consistency across all food records. A list of assumptions and decisions was kept during the food record entry process, see Appendix H.

The FoodWorks file for each participant was checked over once with reference to the paper copy of the food record to ensure consistency was maintained in data entry and that all foods were included. A spot-check was conducted the food records to double-check for consistency and any mistakes.

The nutritional break-down was downloaded from FoodWorks into Microsoft excel, where nutrient values were assessed for any outliers and for any missing values. Where outliers existed, the food record for that participant was checked again to make sure all food types and amounts were entered for correctly. An example of this is where one participant had very high total vitamin A equivalents, but upon checking the original food record and FoodWorks file it could be seen that this participant consumed a lot of chicken liver and carrots. However in other cases, there may have been an error in the food record entry into FoodWorks, for example 40 muesli bars instead of four muesli bars.

3 6.2 Data analysis

DDQ

Analysis of DDQ data involved calculating dietary diversity scores (DDS) and food variety scores (FVS) from the DDQ. The DDS is a count of the food groups consumed, from a total of 25 food groups. The FVS is a count of the individual food items consumed, from a possible 237 food items. The nutritious and discretionary DDSs were also calculated, based on 16 nutritious food groups and 9 discretionary food groups. Similarly, nutritious and discretionary FVSs were calculated, based on 143 nutritious foods and 94 discretionary foods, respectively.

Based on previous dietary diversity research, the variety in the number of nutritious food items eaten and food items eaten overall (nutritious FVS and overall FVS, respectively), were classified into

low, medium and high variety groups. Low variety was less than 30 food items, medium variety was between 31 and 60 food items, and high variety was 61 or more food items (Matla, 2008).

Food records – Dietary diversity

The dietary diversity measures DDS and FVS were calculated from the food record data which was entered into the dietary diversity excel spread sheet. With the food records only covering four days, and the DDQ covering seven days, the food record derived dietary diversity scores were adjusted to get estimated scores for seven days. This was done by multiplying food record dietary diversity scores by seven, and dividing this by four to give scores from the food record that estimated dietary diversity over seven days.

Food records – Nutrients

Validation scores were developed from the food record to assess the ability of the DDQ to assess adequate and optimal nutrient intakes. The validation scores nutrient adequacy ratio (NAR) and mean adequacy ratio (MAR) were calculated using estimated average requirements (EARs). A new, novel approach of validation was created in this research study to account for the over-nutrition in the developed country setting. New validation scores, namely the nutrient optimisation ratio (NOR) and the mean optimisation ratio (MOR) were calculated using the RDIs instead of the EARs, as it was assumed that participants would be more likely to reach nutrient adequacy in an environment where food is abundant. Adequate Intake (AI) was used for nutrients were EAR or RDI were not available. These EAR, RDI and AI values are the nutrient reference values for Australia and New Zealand which were developed by the Ministry of Health and the National Health and Medical Research Council (NHMRC) (National Health and Medical Research Council, 2006). The nutrients for which NAR were calculated were selected based on nutrients used in previous dietary diversity research, as well as nutrients significant to New Zealand women. These were energy, protein, fat, carbohydrate, vitamin A, vitamin C, thiamine, riboflavin, niacin, folate, vitamin B6, vitamin B12, iron, zinc, calcium, selenium and iodine. The commonly investigated nutrients in developing countries are vitamin A, vitamin C, thiamine, riboflavin, iron and calcium (see table 2.3).

To calculate the NAR for each nutrient, the amount of nutrient consumed was divided by the EAR (e.g. for vitamin C, the mean intake estimated from the food record of 102.25mg by divided by the EAR of 30mg, giving an NAR of 3.41). The NARs for the 13 micronutrients were then summed and divided by the total number of NARs to provide the MAR. Energy and macronutrients were not included in the MAR because in this study the MAR is a reflection of micronutrient adequacy of the diet. The NARs were truncated (NAR values that greater than one were reduced to a value of one) in order to avoid compensation of nutrients that were consumed in low amounts when calculating

MAR. As seen in the vitamin C example above, some NARs were well above a value of one, but it is important that this does not compensate for nutrient consumption below the recommended intake. A value of one (or 100%) for MAR indicates that micronutrient intakes are adequate (Steyn *et al.*, 2006).

A similar approach was used to calculate the NOR and MOR values using RDI instead of EAR. For each nutrient, the amount of nutrient consumed was divided by the RDI. The NORs for 13 micronutrients were summed and divided by the total number of NORs, giving the MOR. Again, energy and macronutrients were not included in the MOR calculation because in this study the MOR was used as a reflection of optimal micronutrient intake. Truncated NOR and MOR values were also calculated. A MOR value of one (or 100%) indicates that micronutrient intakes are optimal.

To estimate energy requirements for each participant in this study, the Schofield equation was used (Schofield, 1985; UK Department of Health, 1991). As the physical activity level of these women was unknown, an average physical activity level (PAL) of 1.7 was used as an estimate of physical activity level for all participants. This may have been an overestimate (or underestimate) of physical activity levels for some women. The Goldberg method (Black, 2001) was used to assess energy intake in this subsample of women. A cut-off based on energy intake over four days (food record), basal metabolic rate (estimated from Schofield (Schofield, 1985)) and PAL (a lower value of 1.55 used) was created to estimate the number of participants under-reporting. While the Goldberg cut-off method estimates the under-reporters, there is no consensus as to whether under-reporters should be removed prior to data analysis (Heath, Skeaff, & Gibson, 2000).

3 6.3 Statistical analysis

All data was entered into Statistical Package for Social Sciences (SPSS) for Windows software, (version 22.0, Armonk, NY: IBM Corp) for coding and analysis. The data was tested for normality using Shapiro-Wilk tests, Kolmogorov-Smirnov tests and normality plots. Where data was not normally distributed, the data was log transformed and then tested again for normality. Descriptive statistics were used to describe demographic characteristics, DDQ data and food record data (n=101). Mean ± SD was used for parametric data, median (25, 75 percentile) was used for non-parametric data, and frequency summary statistics for categorical data. The dietary diversity measures, DDS and FVS, were calculated from the DDQ and food record. The food record scores were then adjusted from four to seven days to be comparable with the DDQ scores, and hence assessment the validity of the DDQ to measure dietary diversity could be conducted. Comparisons were made between food group-specific FVS calculated from the DDQ and adjusted food record-derived food group-specific FVS using the Wilcoxon Signed Rank Test to determine whether they

were significantly different. Comparisons were also made between food group-specific FVSs calculated from the DDQ and food record using Spearman correlation coefficients to assess whether they were significantly correlated. The DDS and FVS from the DDQ were compared with the validation scores, NAR, MAR, NOR and MOR calculated from the food records using Spearman correlation coefficients. Comparisons between dietary diversity measures, nutrient intake and validation scores were made using bivariate correlations to determine the DDQs relative validity. Cross-tabulation of the DDS and FVS was conducted to investigate the extent to which food items and food group counts were able to predict the MAR and MOR. The sensitivity and specificity analysis to determine the ability of DDS and FVS cut-offs to accurately reflect diet quality could not be conducted as too many of the participants were meeting the MAR or had an MAR over one (most of the participants consumed nutritionally adequate diets already). This is why the new, novel validation scores NOR and MOR were developed.

4. Results

This research study was conducted in a subsample of women participating in the Women's EXPLORE Study at Massey University. All women completed a dietary diversity questionnaire (DDQ) and a four-day weighed food record. This chapter describes the results of the study. The characteristics of the women are presented first, followed by the dietary diversity and food variety of women's intake over seven days, and then by the results from the DDQ, specifically intake and patterns of food items and food groups. Data from the weighed food records are then presented, describing nutrient intake, nutrient adequacy and nutrient optimisation. Finally, the validation results are presented, comparing data from the DDQ and four-day weighed food records.

4.1 Characteristics of the Sample

Details of recruitment of women for the Women's EXPLORE Study through to the final number of participants included in the data analysis for this study are shown in figure 4.1.

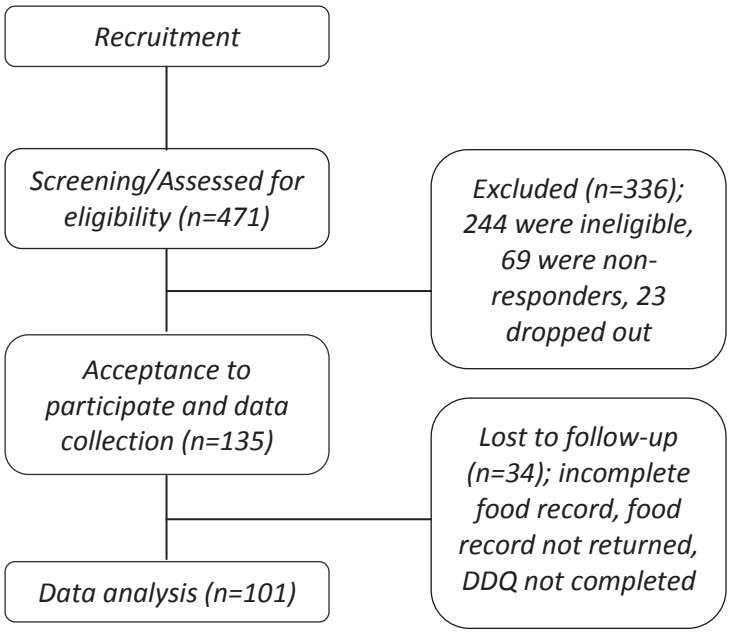


Figure 4.1 - Flow diagram of recruitment, screening and final number of participants for data analysis

Of the 135 included participants, a total of 101 completed the study. There were 34 participants lost to follow-up due to food records not having four full days of recording, food records not being returned and DDQs not being completed online or returned. The 'snack food' group data from the DDQ was missing for three participants, however the rest of their DDQ data was included in the analysis. Therefore, the 'snack food' data included is based on 98 participants.

Demographic characteristics of the participants are presented in table 4.1. The majority of women were 25 – 45 years (40.6%), and of NZ European ethnicity (82.2%). The median (25, 75percentile) body mass index (BMI) was 23.3 (21.1, 26.1) kg/m^2, and most women had a normal BMI (68.3%). Nearly one-third (32.3%) had a high BMI (≥25kg/m^2), with 13.1% of women classified as obese (≥30kg/m^2). Mean body fat percentage was 30.5 ± 7.3%. Nearly half (45.5%) had a normal body fat percentage and over half (53.5%) were in the high body fat percentage category.

Table 4.1 - Summary of demographic characteristics of a subsample of women from the Women's EXPLORE Study (n=101)

Characteristics	**n (%)**
Age (years)	32.1 ± 7.4[*]
Age groups	
16-25	21 (20.8)
25-35	41 (40.6)
35-45	39 (38.6)
Ethnicity	
New Zealand European	83 (82.2)
Māori	11 (10.9)
Pacific	7 (6.9)
Height (cm)	167.7 ± 6.1[1]
Weight (kg)	66.8 (59.1, 73.5)[2]
BMI (kg/m²)	23.1 (21.1, 26.1)[2]
BMI category	
Low (<18.5 kg/m²)	0 (0)
Normal (18.5-24.9 kg/m²)	69 (68.3)
High (>25 kg/m²)	32 (31.7)
Body fat % (% of total body weight)	30.5 ± 7.3[1]
Body fat % category	
Low, (<18%)	1 (1.0)
Normal, (18-28%)	46 (45.5)
High, (>28%)	54 (53.5)
Waist circumference (cm)	73.8 (69.1, 80.5)[2]
Hip circumference (cm)	101.1 (97.1, 106.0)[2]

BMI, body mass index
[1]Mean ± SD used for normally distributed data
[2]median (25, 75 percentiles) used for not normally distributed data

4.2 Dietary Diversity and Food Variety

The dietary diversity score (DDS) provides a count of food groups consumed, and the food variety score (FVS) provides a count of food items consumed. Table 4.2 shows the mean and median DDS and FVS, as well as ranges and maximum possible scores. The median DDS was 23, with scores ranging from 13 – 25. The median FVS was 75, with scores ranging from 17 – 160.

Table 4.2 – The average dietary diversity of the subsample of women over a seven day period (n=101)

Score	Median (25, 75 percentile)	Range	Maximum score achievable
DDS	23 (21, 23)	13 – 25	25
Nutritious DDS	15 (14, 16)	8 – 16	16
Discretionary DDS	7 (7, 8)	4 – 9	9
FVS	75 (61, 87)	17 – 160	237
Nutritious FVS	49 (41, 59)	8 – 107	143
Discretionary FVS	25.61 ± 9.99[1]	9 – 58	94

DDS, dietary diversity score; FVS, food variety score
Low FVS: 0 – 30 food items; medium FVS: 31-60 food items; high FVS: 61 or more food items (Matla, 2008)
[1]Mean ± SD for normally distributed data

4.2.1 Food groups

The maximum number of food groups (25) was consumed by 10.9% of participants. The lowest number of food groups consumed was 13 (1.0% of participants). Nearly one-third (29.7%) consumed 23 food groups. The median DDS for nutritious food groups was high, with a median score of 15. The lowest number of nutritious food groups consumed was eight out of 16 and was only consumed by 1.0% of participants. The median DDS for discretionary food groups was seven, and 15.8% of participants consumed the maximum discretionary food groups of nine.

4.2.2 Food items - Nutritious

Table 4.3 shows the breakdown of nutritious food groups, and details the number of nutritious food items consumed by the number of participants. From a possible 6 meats to choose from, most participants (34) ate one individual meat item. Most participants ate no fish or seafood food items (26 participants). Only 7 out of 101 participants did not consume eggs (see table 4.3). Two cheese items were eaten by 53 participants. Within the vitamin A-rich fruits and vegetables group, most participants (19) consumed eight food items.

The mean ± SD nutritious FVS was 50.36 ± 15.74, and most participants (75) consumed a medium variety (31-60 food items) of nutritious food items (Matla, 2008). The most common nutritious FVS was 55 food items, and six participants consumed this number (data not shown).

Table 4.3 – Food variety scores within each nutritious food group and nutritious FVS (n=101)

	1. Meat	2. Poultry	3. Fish and seafood	4. Eggs	5. Dairy Products - nutritious	6. Cheese	7. Breads	8. Cereals	9. Starchy vegetables	10. Legumes	11. Nuts and seeds	12. Vitamin A-rich fruits and vegetables	13. Vitamin C-rich fruits and vegetables	14. Other fruits	15. Other vegetables	16. Oils and Fats	Nutritious FVS
Food items in group	6	4	9	1	9	2	6	13	9	7	5	23	14	12	15	8	143
Mean ± SD	1.82 ± 1.15	1.18 ± 0.59	1.92 ± 1.12	0.93 ± 0.26	2.76 ± 1.23	1.48 ± .59	2.40 ± 1.04	4.64 ± 2.05	2.11 ± 1.39	1.51 ± 1.49	1.84 ± 1.08	8.20 ± 3.00	4.54 ± 2.31	4.95 ± 2.27	7.13 ± 2.74	2.94 ± 1.33	50.36 ± 15.74
Range used	0-5	0-3	0-8	0-1	0-6	0-2	0-5	0-10	0-6	0-7	0-4	0-19	0-11	0-11	0-14	0-7	8-107
Breakdown of usage (number of food items eaten = number of participants that ate this number of food items)	0=11 **1=34** 2=26 3=24 4=4 5=2	0=8 **1=69** 2=22 3=2	**0=26** 1=25 2=17 3=15 4=8 5=5 6=3 7=1 8=1	0=7 **1=94**	0=3 1=13 2=23 **3=36** 4=20 5=4 6=2	0=5 1=43 **2=53**	0=1 1=20 **2=35** 3=30 4=12 5=2	0=3 1=2 2=5 3=16 **4=29** 5=17 6=13 7=7 8=2 9=5 10=2	0=11 1=24 **2=30** 3=26 4=5 5=2 6=4	**0=32** 1=26 2=18 3=15 4=6 5=3 7=1	0=12 1=26 **2=34** 3=24 4=5	0=1 2=0 3=2 4=2 5=5 6=17 7=16 **8=19** 9=12 10=9 11=4 12=4 13=3 14=3 15=1 16=0 17=1 19=1	0=2 1=3 2=13 **6=17** 4=12 5=8 6=14 7=14 8=4 9=3 11=2	0=2 1=6 2=6 3=10 **4=20** 5=17 6=15 7=12 8=9 9=1 10=1 11=2	0=3 2=3 3=3 4=8 5=9 6=10 7=17 8=15 **9=18** 10=6 11=4 12=3 13=1 14=1	0=1 1=10 **2=32** 3=26 4=20 5=8 6=3 7=1	0-30=6 **31-60=75** 61+=20

FVS, food variety score ; SD, standard deviation
Low FVS: 0 – 30 food items; medium FVS: 31-60 food items; high FVS: 61 or more food items (Matla, 2008)

4.2.3 Food items - Discretionary

Table 4.4 shows the breakdown of discretionary food groups and all food groups, and details the number discretionary food items and all food items consumed by the number of participants. The most commonly consumed number of food items in each food group is in bold. The table also shows the total FVS in the final column, as discussed in section 4.2.2.

The majority of participants (32) consumed one discretionary flesh food group item. Most participants (43) consumed no discretionary dairy food products, and most (63) consumed no discretionary breads, cereals and starchy vegetables food items. The most commonly consumed number of alcohol items was one (27 participants) or two (27 participants). Most participants (18) ate seven sauces, spreads and flavourings food items.

The mean ± SD discretionary FVS was 25.61 ± 9.99. The most common discretionary FVS was 32 individual food items (eight participants), followed by 17 individual food items (seven participants) (data not shown).

4.2.4 Food items – All foods

The far right column in table 4.4 shows the breakdown of all food items and their consumption by participants. The most commonly consumed number of food items in each food group is in bold. The mean FVS was 76, indicating an overall high food variety. There was a large range of food items consumed (17-160 food items). The most common number of foods items consumed over the seven days was 66, 67 and 72, with five participants consuming each of these numbers of foods items.

Out of the 143 nutritious food items available in the DDQ, 71.7% were consumed. Out of the possible 94 discretionary food items available, 24.1% were consumed. The number of nutritious and discretionary food items that made up the median FVS of 76 was about 50.4 food items nutritious food items 25.6 items discretionary food items.

Table 4.4 – Food variety scores within each discretionary food group and discretionary FVS, and total FVS (n=101)

	1. Flesh foods - Discretionary	2. Dairy Products - Discretionary	3. Breads, cereals and Starchy Vegetables - Discretionary	4. Drinks	5. Alcohol	6. Sauces, spreads and flavourings	7. Sweet snacks	8. Savoury snacks[1]	9. Takeaways and fast-food	FVS discretionary	Total FVS; and total number of food items consumed
Food items in group	8	6	5	15	7	19	12	9	13	94	(n = 236)
Mean ± SD	1.78 ± 1.46	0.90 ± 0.95	0.49 ± 0.76	3.68 ± 1.59	1.70 ± 1.21	7.42 ± 2.99	4.54 ± 2.07	2.27 ± 1.57	2.83 ± 2.22	25.61 ± 9.99	76 ± 24
Range used	0-6	0-4	0-4	0-8	0-5	1-17	1-10	0-7	0-10	9-58	17-160
Breakdown of usage (number of food items eaten = number of participants that ate this number of food items)	0=19	**0=43**	**0=63**	0=1	0=19	0=0	0=0	0=12	0=16	**0-30=71**	0-30=2
	1=32	1=31	1=31	1=6	**1=27**	1=1	1=5	**1=24**	1=11	30-60=30	30-60=22
	2=25	2=23	2=4	2=13	**2=27**	2=2	2=12	**2=24**	2=22	61+=0	**61+=77**
	3=9	3=2	3=2	**3=32**	3=22	3=6	3=16	3=20	**3=23**		
	4=10	4=2	4=1	4=23	4=5	4=7	**4=21**	4=10	4=11		
	5=5			5=11	5=1	5=10	5=18	5=5	5=7		
	6=1			6=9		6=10	6=11	6=2	6=3		
				7=5		**7=18**	7=8	7=1	7=3		
				8=1		8=15	8=5		8=2		
						9=9	9=4		9=2		
						10=9	10=1		10=1		
						11=5					
						12=3					
						13=1					
						14=0					
						15=3					
						16=0					
						17=1					

FVS, food variety score; SD, standard deviation

[1]n=98 due to missing data for savoury snacks food group

4.3 Patterns of Food Intake

4.3.1 Food item and food group categorisation

A total of 237 food items and 25 food groups were included in the final DDQ. There were 143 nutritious individual food items and 16 nutritious food groups, including meat; poultry; fish and seafood; eggs; dairy products; cheese; breads; cereals; starchy vegetables; legumes; nuts and seeds; vitamin A-rich fruits and vegetables; vitamin C-rich fruits and vegetables; other fruits; other vegetables; and oils and fats. There were 94 discretionary individual foods items and nine discretionary food groups, including flesh foods (discretionary); dairy products (discretionary); breads, cereals and starchy vegetables (discretionary); drinks; alcohol; sauces, spreads and flavourings; sweet snacks; savoury snacks; and takeaway and fast-foods.

4.3.2 Food groups

Table 4.5 shows the proportion of participants that consumed each of the food groups over the seven day period. The only two food groups from which 100% of participants ate were sauces, spreads and flavourings, and sweet snacks (both discretionary food groups). The food groups consumed the least were fish and seafood (74.3%); legumes (68.3%); and discretionary breads, cereals and starchy vegetables (37.6%).

4.3.3 Food items

The top 25 most commonly consumed food items are shown in table 4.6. Of these 25 food items, 20 belonged to nutritious food groups. The most commonly consumed food items were water (99.9%), oil (98%), and eggs (94.9%). The discretionary foods water; tomato sauce, BBQ sauce etc; chocolate; salt; and wine were in the list. No food items from the following food groups were in the top 25 food list: seafood or fish; discretionary meat, fish, or poultry; legumes; savoury snacks; and takeaway and fast-food.

The only food items from the DDQ that were not consumed by any participants were hocks, pork bones, pigs head; kava; battered hot dog; and bhuja mix. Additional food items mentioned by participants in the 'other' section of the DDQ were gherkins; olives; roti/naan bread; kale; pomegranate; dairy blend; pastry; cereal and muesli bars; crumbed or battered shellfish; and vegetable crisps.

Table 4.5 - Consumption of food groups measured by DDQ in women (n=101)

Food group	Participants consuming the food group n (%)
Sauces, spreads and flavourings	101 (100)
Sweet snacks	101 (100)
Vitamin A-rich fruits and vegetables	100 (99)
Oils and fats	100 (99)
Drinks	100 (99)
Breads	100 (99)
Vitamin C-rich fruits and vegetables	99 (98)
Other fruits (and juices)	99 (98)
Nutritious dairy products	98 (97)
Other vegetables	98 (97)
Cereals	98 (97)
Cheese	96 (95)
Discretionary dairy products	96 (95)
Eggs	94 (93)
Poultry	93 (92)
Meat	90 (89)
Starchy vegetables	90 (89)
Savoury snacks[1]	89 (88)
Nuts and seeds	89 (88)
Takeaways and fast-food	86 (85)
Discretionary flesh foods	83 (82)
Alcohol	82 (81)
Fish and seafood	75 (74)
Legumes	69 (68)
Discretionary breads, cereals, starchy vegetables	38 (38)

[1]n=98 for snacks food group, as snack food group data from the DDQ was missing for three participants

Table 4.6 - Most commonly eaten food items (from a list of 237 foods) in women (n=101)

Ranking of top 25 foods	Food/drink Item	Participants consuming the food item n (%)
1	Water*	99 (98%)
2	Oil	97 (96%)
3	Eggs	94 (93)
4	Carrots	93 (92)
5	Lettuce	92 (91)
6	Chicken	91 (90)
7	Hard cheese	90 (89)
8	Banana	89 (88)
9	Tomato	89 (88)
10	Onion	89 (88)
11	Tomato sauce, BBQ sauce, sweet chilli sauce, mustard sauce etc[1]	89 (88)
12	Chocolate[1]	86 (85)
13	Broccoli	84 (83)
14	Beef	83 (82)
15	Nuts	83 (82)
16	Rice	80 (79)
17	Garlic	79 (78)
18	Spinach	78 (77)
19	Cucumber	77 (76)
20	Green beans	76 (75)
21	Bread or rolls, whole-wheat	75 (74)
22	Salt[1]	72 (71)
23	Capsicum, red	72 (71)
24	Avocado	71 (70)
25	Wine[1]	70 (69)

[1]food item belongs to discretionary food group

4.4 Intakes of Nutrients and Nutrient Adequacy

Data from food records was used to provide information on nutrient intake, nutrient adequacy and nutrient optimisation (see table 4.7).

Energy requirements were not met by the majority of the women (96%), as per the Schofield equation (Schofield, 1985). The Goldberg method (Black, 2001) identified seventy-six (75.2%) participants as under-reporters, based on reported energy intake from the weighed four day food record.

All women met the protein EAR and RDI in terms of daily grams of protein intake, and the average NAR and NOR were 2.31 ± 0.64 and 1.86 ± 0.51, respectively. On average, fibre intake was adequate

with the NAR being 1.07 ± 0.68. Despite this, 58.4% did not meet the AI for fibre. The percentage of women who did not meet the recommended intake of saturated fat (8-10% of total energy intake) was 82.2%. A large proportion (80.2%) of women did not meet the sugar recommendation as a percentage of total energy recommendations (≤15% of total energy intake). No women were within the AI range for sodium intake.

Iodine was the only micronutrient to have a NAR below one and most participants (94.1%) were not meeting the EAR for iodine. Vitamin B12 had the greatest range of nutrient intake with NAR values ranging from 0.55-24.67. Iron, calcium, iodine and zinc all had NORs less than one. Although the mean NAR and NOR were over one for selenium, a relatively large percentage of the participants did not meet selenium EAR (46.5%) and RDI (72.3%).

The truncated MAR was 0.94 ± 0.04, suggesting near adequate nutrient intake. The truncated MOR was 0.84 ± 0.16, suggesting the average nutrient intake were not completely optimal (value of 1 represents 100% consumption of nutrient recommendations). These were calculated based on the NAR for 13 micronutrients (thiamine, riboflavin, niacin, folate, vitamin B6, vitamin B12, vitamin C, vitamin A, iron, calcium, selenium, iodine and zinc).

Table 4.7 –Average daily nutrient intakes, nutrient adequacy and nutrient optimisation in women (n=101)

Nutrient and unit of measure	Food record intake (mean ± SD)	EAR	% of participants not meeting EAR	NAR (mean ± SD)	Range of NARs	RDI	% of participants not meeting RDI	NOR (mean ± SD)	Range of NORs
Energy (kJ)	7907.81 ± 1746.62	10317.65 ± 1154.16[1]	96	0.77 ± 0.18	0.41 - 1.77	-	-	-	-
Total protein (g, % TE)	85.57 ± 23.74, 18.11 ± 3.94	37, 15-25[2, 3]	0 for grams protein; 20.8 for % energy from protein	2.31 ± 0.64	1.27 - 5.50	46[7]	0	1.86 ± 0.51	1.02 – 4.42
Total fat (g, % TE)	76.14 ± 23.05, 34.50 ± 6.98	20-35[2]	46.5	-	-	-	-	-	-
α-linolenic acid,n-3 (g, % TE)	0.464 ± 0.363g	0.8[3], 0.4-1[2]	87.1	0.58 ± 0.45	0.10 - 2.59	-	-	-	-
Polyunsaturated fat (% TE)	5.76 ± 2.25	6-10[4]	68.3	-	-	-	-	-	-
Monounsaturated fat (% TE)	12.99 ± 3.36	10-20[4]	22.8	-	-	-	-	-	-
Saturated fat (% TE)	12.65 ± 3.54	8-10[2]	82.2%	-	-	-	-	-	-
Carbohydrates (g, % TE)	204.23 ± 58.60, 41.58± 7.32	45-65[2]	70.3	-	-	-	-	-	-
Sugars (g, % TE)	95.64 ± 31.36, 20.71 ± 5.36	≤15[4]	80.2	-	-	-	-	-	-
Fibre (g)	26.68 ± 16.91	25[3,5]	58.4	1.07 ± 0.68	0.43 - 6.21	-	-	-	-
Thiamine (mg)	1.50 ± 0.75	0.9	14.9	1.67 ± 0.83[6]	0.69 - 5.44	1.1	32	1.37 ± 0.68[8]	0.57 ± 4.45
Riboflavin (mg)	2.13 ± 0.66	0.9	0	2.36 ± 0.73[6]	1.10 - 5.56	1.3[7]	2	1.64 ± 0.50[8]	0.76 – 3.85
Niacin (mg)	17.83 ± 6.18	11	8.9	1.62 ± 0.56[6]	0.55 - 3.40	14	25.7	1.27 ± 0.44[8]	0.43 – 2.68
Total folate (µg)	408.62 ± 173.28	320	36.6	1.28 ± 0.54[6]	0.46 - 3.90	400	52.5	1.02 ± 0.43[8]	0.36 – 3.12
Vitamin B6 (mg)	2.16 ± 1.06	1	5.9	1.96 ± 0.96[6]	0.77 - 6.29	1.3[7]	9.9	1.66 ± 0.81[8]	0.65 – 5.32
Vitamin B12 (µg)	4.46 ± 5.06	2	5.9	2.23 ± 2.53[6]	0.55 - 24.67	2.4	14.9	1.86 ± 2.11 [8]	0.46 – 20.56
Vitamin C (mg)	102.25 ± 57.23	30	7.9	3.41 ± 1.91[6]	0.38 - 9.95	45[7]	10.9	2.28 ± 1.27[8]	0.25 – 6.63
Vitamin A (RE) (µg)	945.12 ± 964.76	500	17.8	1.89 ± 1.93[6]	0.45 - 18.44	900[7]	62.4	1.05 ± 1.07[8]	0.25 – 10.25
Iron (mg)	13.16 ± 4.75	8	4	1.64 ± 0.59[6]	0.81 - 5.65	18[7]	92.1	0.74 ± 0.26[8]	0.36 – 2.51
Calcium (mg)	952.85 ± 328.87	840	38.4	1.13 ± 0.39[6]	0.44 - 2.85	1000[7]	62.4	0.95 ± 0.33[8]	0.37 – 2.39

Table 4.7 –Average daily nutrient intakes, nutrient adequacy and nutrient optimisation in women (n=101)

Nutrient and unit of measure	Food record intake (mean ± SD)	EAR	% of participants not meeting EAR	NAR (mean ± SD)	Range of NARs	RDI	% of participants not meeting RDI	NOR (mean ± SD)	Range of NORs
Selenium (µg)	72.43 ± 82.43	60[7]	46.5	1.45 ± 1.65[6]	0.38 - 15.61	70[7]	72.3	1.04 ± 1.18[8]	0.27 -11.15
Iodine (µg)	66.71 ± 49.20	100	94.1	0.67 ± 0.49[6]	0.14 - 4.18	150	96	0.44 ± 0.32[8]	0.09 – 2.79
Zinc (mg)	10.70 ± 3.47	6.5	4	1.65 ± 0.53[6]	0.85 - 4.77	14[7]	88.1	0.77 ± 0.26[8]	0.40 – 2.21
Sodium (mg)	2530.78 ± 1141.33	460-920[4]	100	2.75 ± 1.24	1.07 - 11.90	-	-	-	-
MAR	-	-	-	**1.77 ± 0.58**	**0.89 – 5.00**	-	-	-	-
MAR truncated	-	-	-	**0.94 ± .04**	**.78 – 1.00**				
MOR	-	-	-	-	-			**1.24 ± 0.51**	**0.44 – 2.28**
MOR truncated	-	-	-	-	-			**0.84 ± 0.16**	**0.42 – 0.99**

EAR, estimated average requirement; NAR, nutrient adequacy ratio; NOR, nutrient optimisation ratio; LC n-3, long chain fatty acid; AI, adequate intake; RDI, recommended daily intake; % TE, percentage of total energy, MAR, mean adequacy ratio; MOR, mean optimisation ratio.

[1]Energy requirements based on mean BMR from Schofield equation multiplied by an estimated physical activity factor (PAL) of 1.7 and then converted from kcal to kJ. **Schofield equation:** UK Department of Health. (1991). *Dietary reference values for food energy and nutrients for the United Kingdom: Report of the panel on dietary reference values of the committee on medical aspects of food policy*. London: Her Majesty's Stationary Office.

PAL: Eilia, M. (2005). Insights into energy requirements in disease. *Public Health Nutrition, 8*, 1037-1052.

[2] AMDR (acceptable macronutrient distribution range), used where EAR, RDI and AI not available or in addition to EAR. Values obtained from: National Health and Medical Research Council. (2006). *Nutrient reference values for Australia and New Zealand including recommended dietary intakes*. Wellington, Canberra: Ministry of Health, NHMRC.

[3]For participant (n=1) aged 18 years, the EARs specific to their age used were protein 35g, LC n-3 85mg, saturated fat ≤10%, fibre 22g, total folate 330µg, 1mg vitamin B6, vitamin C 28mg, vitamin A 485µg, calcium 1050mg, selenium 50µg, iodine 95µg, zinc 6mg

[4]Polyunsaturated, monounsaturated and saturated fat recommended intakes based on Ministry of Health. (2003). Food and Nutrition Guidelines for Healthy Adults: A Background Paper. Wellington: Ministry of Health; and Ministry of Health. (2012). Food and nutrition guidelines for healthy children and young people (aged 2–18 years): A background paper. Wellington: Ministry of Health.

[5]AI used where EAR or RDI not available

[6] Included in MAR calculation

[7]For participant (n=1) aged 18years, the RDIs specific to their age used were protein 45g, riboflavin 1.1mg, vitamin B6 1.2mg, vitamin C 40mg, vitamin A 700 µg, iron 15mg, calcium 1300mg, selenium 60µg, zinc 7 µg

[8] Included in MOR calculation

4.5 Validity of the DDQ

4.5.1 Comparing dietary diversity measures scores from DDQ and food records

Table 4.8 shows the number of food items and food groups consumed from the DDQ and the food record, the adjusted measures from the food record, and correlations between scores from the DDQ and the adjusted measures from the food record. The adjusted median dietary diversity measures calculated from the food record are similar to the median dietary diversity measures calculated from the DDQ. All of the DDSs and FVSs from the two methods are significantly correlated ($P<0.05$ and $P<0.01$). Discretionary FVS had the strongest correlation between the two methods, but they were only weakly correlated ($r_s=.387$)

Table 4.9 compares the median number of food items consumed from each food group derived from the DDQ and the food record (adjusted to seven days). There is no significant difference in the median FVS from the different dietary assessment methods for 15 out of the 25 food groups. This suggests that the numbers of food items consumed from these 15 food groups are similar, and that therefore the DDQ and food record measure dietary diversity similarly. The FVS for each of these 15 food groups that were not significantly different between the DDQ and food record only varied around 1 to 3 food items.

The median FVS for each food group from the DDQ and food record are all significantly correlated, except for the two food groups, discretionary breads, cereals and starchy vegetables and the vitamin A-rich fruits and vegetables. The number of food items as measured by the DDQ is similar to that of the food record. The fish food group's FVS derived from the two different dietary assessment methods have a strong, positive correlation (Spearman's $r_s=..610$). The discretionary dairy groups FVS derived from the two different dietary assessment methods have a weak, negative correlation ($r_s=..253$).

Table 4.8 – Comparison of dietary diversity measures between DDQ and food record (n=101)

Score	Maximum score achievable	Median (25, 75 percentile) (DDQ)	Median (25, 75 percentile) (FR)	Range (DDQ)	Range (FR)	Adjusted median (25, 75 percentile) (FR)[1]	Spearman's correlation (r_s)[3]	Significance (two-tailed) (P)
DDS	25	23 (21, 23)	18 (17, 19)	13 – 25	12 - 22	31.3 (29.8, 33.3)	.328	.001**
Nutritious DDS	16	15 (14, 16)	13 (12, 14)	8 – 16	9 - 16	22.8 (21, 24.5)	.338	.001**
Discretionary DDS	9	7 (7, 8)	6 (5, 7)	4 – 9	3 – 8	10.5 (8.8, 12.3)	.250	.012*
FVS	237	75 (61, 87)	44.66 ± 10.13[2]	17 – 160	24 – 67	78.2 ± 17.7[2]	.216	.030*
Nutritious FVS	143	49 (41, 59)	29.07 ± 7.18[2]	8 – 107	13 – 48	50.9 ± 12.6[2]	.214	.032*
Discretionary FVS	94	25.61 ± 9.99[2]	15.59 ± 4.81[2]	9 – 58	3 – 31	27.3 ± 8.4[2]	.387	.000**

DDQ, dietary diversity questionnaire; FR, food record; DDS, dietary diversity score; FVS, food variety score; SD, standard deviation

Low FVS: 0 – 30 food items; medium FVS: 31-60 food items; high FVS: 61 or more food items

[1]Food record scores were adjusted to estimate seven day scores to match the DDQ time period. Food record scores were divided by four and multiplied by seven to give the adjusted score

[2]Mean ± SD for normally distributed data

[3]Spearman's correlation conducted to compare dietary diversity measures from DDQ and adjusted measures from the food record

*Statistical significance at P<0.05

**Statistical significance at P<0.01

Table 4.9 – Comparison of DDQ-derived food group-specific FVS and adjusted FR-derived food groups-specific FVS (n=101)

Food group	Median FVS (25^{th}, 75^{th}) (DDQ)	Median FVS (25^{th}, 75^{th}) (FR)	Significance difference in FVS (Wilcoxon test, 2-tailed)	Spearman's correlation (r_s)	Significance of correlation (two-tailed) (P)
1. Meat	2 (1, 3)	1 (0, 2)	0.885	.409	0.00**
2. Poultry	1 (1, 1)	1 (1, 1)	0.00**	.476	0.00**
3. Fish and seafood	1 (0, 3)	1 (0, 1)	0.224	.610	0.00**
4. Discretionary flesh Foods	1 (1, 2)	1 (0, 1)	0.575	.498	0.00**
5. Eggs	1 (1, 1)	1 (0, 1)	0.423	.241	0.015*
6. Nutritious dairy Products	3 (2, 4)	2 (1, 3)	0.00**	.465	0.00**
7. Cheese	2 (1, 2)	1 (1, 2)	0.00**	.437	0.00**
8. Discretionary dairy Products	1 (0, 2)	0 (0, 1)	0.00**	-.253	0.11*
9. Breads	2 (2, 3)	2 (1, 3)	0.00**	.402	0.00**
10. Cereals	4 (3, 6)	3 (2, 4)	0.150	.400	0.00**
11. Starchy vegetables	2 (1, 3)	1 (0, 2)	0.732	.414	0.00**
12. Discretionary breads, cereals and starchy vegetables	0 (0, 1)	0 (0, 0)	0.224	.111	0.270
13. Legumes	1 (0, 2)	0 (0, 1)	0.018*	.429	0.00**
14. Nuts and seeds	2 (1, 3)	1 (0, 2)	0.054	.270	0.006**
15. Vitamin A-rich fruits and vegetables	8 (6, 10)	5 (3, 6)	0.624	.181	.070
16. Vitamin C-fruits and vegetables	4 (3, 6)	2 (1, 3)	0.00**	.403	0.00**
17. Other fruits	5 (4, 6)	3 (2, 4)	0.333	.393	0.00**
18. Other vegetables	7 (5, 9)	4 (2, 5)	0.047*	.312	0.002**
19. Oils and vats	3 (2, 4)	2 (1, 2)	0.173	.434	0.00**
20. Drinks	3 (3, 5)	4 (3, 5)	0.00**	.321	0.001**
21. Alcohol	2 (1, 3)	1 (0, 1)	0.188	.484	0.00**
22. Sauces, spreads and flavourings	7 (5, 9)	4 (3, 6)	0.212	.429	0.00**
23. Sweet snacks	4 (3, 6)	2 (1, 4)	0.697	.281	0.004**
24. Savoury snacks	2 (1, 3)	1 (0, 2)	0.052	.319	0.001**
25. Takeaways and fast-food	3 (1, 4)	1 (0, 2)	0.00**	.420	0.00**

DDQ, dietary diversity questionnaire; FR, food record; FVS, food variety scores

* Statistical significance at P<0.05

** Statistical significance at P<0.01

4.5.2 Investigating the relationships between nutrient adequacy/optimisation and dietary diversity

Table 4.10 shows the results of correlation coefficient analysis between the MAR and NARs of nutrients with DDS and FVS. Significant correlations exist between the DDS for nutritious food groups and the MAR (P<0.05); and the individual NAR of vitamin B12 (P<0.01) and selenium (P<0.05). The nutritious DDS was very weakly (r_s=.199) correlated with that of the MAR There were no significant correlations between MAR or NAR and nutritious FVS, showing that the likelihood of meeting the EAR did not increase as the number of food items consumed increased.

Table 4.10 – Correlations between nutritious DDS and nutritious FVS with the MAR and NAR

Truncated NARs and MAR	**Nutritious DDS**		**Nutritious FVS**	
	Spearman's correlation (r_s)	Significance (two-tailed) (P)	Spearman's correlation (r_s)	Significance (two-tailed) (P)
MAR (micronutrients only)	.199	.046*	.099	0.326
NAR energy	.094	0.349	.079	0.429
NAR protein	-	-	-	-
NAR dietary fibre	.151	.123	.049	0.629
NAR thiamine	.161	0.109	.014	0.891
NAR riboflavin	-	-	-	-
NAR niacin	.046	0.648	.039	0.699
NAR total folate	.046	0.635	.024	0.810
NAR vitamin B6	.161	0.107	.083	0.410
NAR vitamin B12	.262	0.003**	.132	0.189
NAR vitamin C	.058	0.568	-.035	0.730
NAR vitamin A (RE)	-.036	0.721	-.112	0.264
NAR iron	-.014	0.888	-.038	0.705
NAR calcium	.008	0.939	-.068	0.501
NAR selenium	.248	0.012*	.141	0.160
NAR iodine	.048	0.634	.026	0.793
NAR zinc	.087	0.384	.112	0.264

DDS, dietary diversity score; FVS, food variety score; MAR, mean adequacy ratio; NAR, nutrient adequacy ratio; RE, retinol equivalents
Could not calculate correlations with NAR of protein and riboflavin because NAR was 1 for all women for these nutrients
Spearman's correlation (r_s) used as data was not normally distributed
* Statistical significance at P<0.05
** Statistical significance at P<0.01

Table 4.11 shows the results of correlation coefficient analysis between the MOR and NORs of nutrients with DDS and FVS. Significant, weak correlations exist between nutritious DDS and the MOR (r_s= .258; P<0.01). There were also significant correlations between nutritious DDS and the NORs for thiamine, vitamin B12 and selenium. There were no significant correlations

between MOR or NOR and nutritious FVS, suggesting that the likelihood of meeting the RDI did not increase as the number of food items consumed increased.

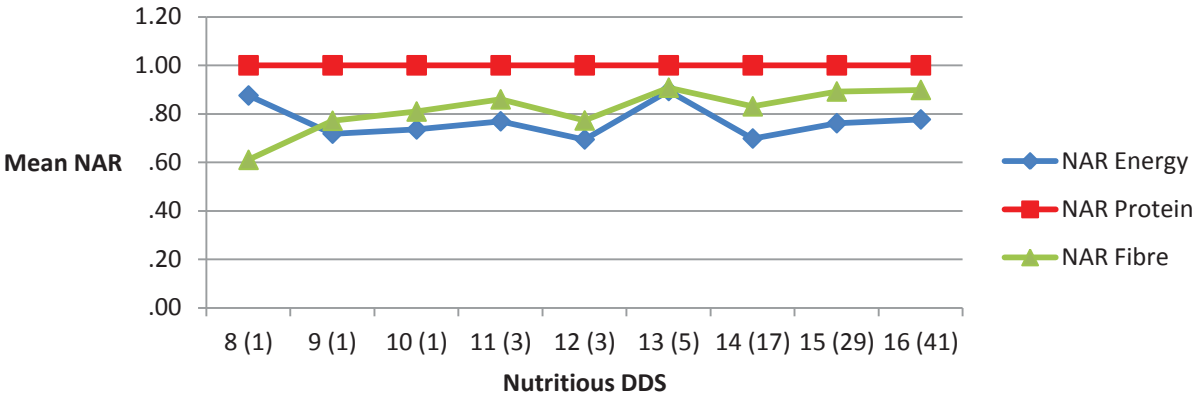
Table 4.11 – Correlations between nutritious DDS and nutritious FVS with the MOR and NOR

Truncated NORs and MOR	Nutritious DDS		Nutritious FVS	
	Spearman's correlation (r_s)	Significance (two-tailed) (P)	Spearman's correlation (r_s)	Significance (two-tailed) (P)
MOR (micronutrients only)	.258	.009**	.101	0.316
NOR thiamine	.201	0.044*	.063	0.529
NOR riboflavin	.162	0.106	.084	0.405
NOR niacin	.045	0.652	-.032	0.752
NOR total folate	.045	0.652	.049	0.626
NOR vitamin B6	.106	0.291	.080	0.425
NOR vitamin B12	.243	0.014*	.152	0.128
NOR vitamin C	.113	0.259	.079	0.432
NOR vitamin A (RE)	.058	0.566	-.011	0.912
NOR iron	-.014	0.888	-.038	0.705
NOR calcium	-.012	0.901	-.048	0.634
NOR selenium	.218	0.029*	.092	0.360
NOR iodine	.049	0.626	.025	0.804
NOR zinc	.087	0.384	.112	0.264

DDS, dietary diversity score; FVS, food variety score; MOR, mean optimisation ratio; NOR, nutrient optimisation ratio; RE, retinol equivalents
Spearman's correlation (r_s) used as data was not normally distributed
* Statistical significance at P<0.05
** Statistical significance at P<0.01

4.5.3 Relationship between the number of nutritious food groups consumed and adequate nutrient intake

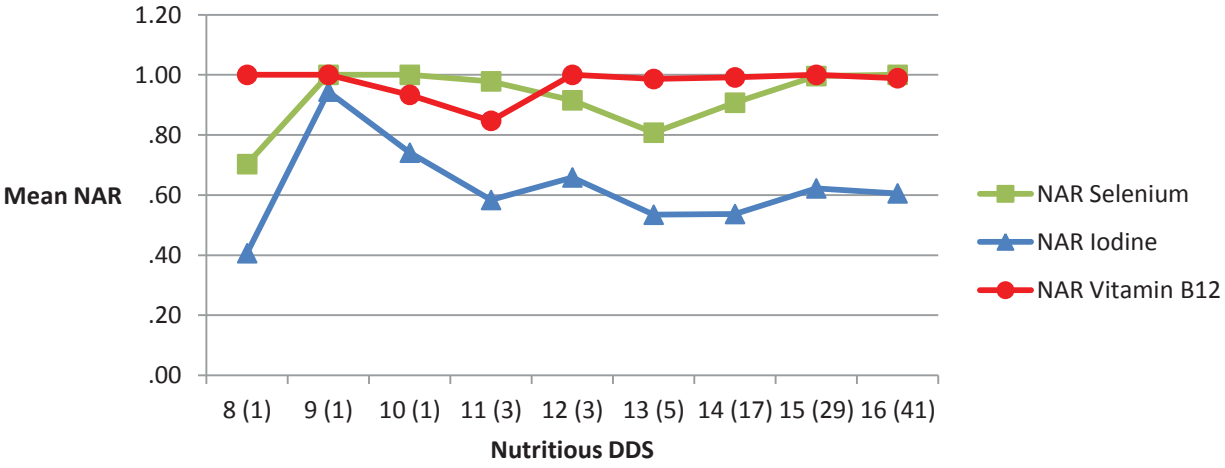
The relationship between the number of nutritious food groups consumed (DDS) and the mean truncated NARs of energy, protein and fibre is shown in figure 4.2. Protein intake is constant at all levels of dietary diversity, indicating adequate protein intake regardless of the number of nutritious food groups consumed. The NAR for energy and fibre increase as the number of nutritious food groups consumed increases.



NAR, nutrient adequacy ratio; DDS, dietary diversity score.
NARs for energy, protein and fibre were not based on EARs, see footnotes of table 4.7

Figure 4.2 – Mean truncated NARs of energy, protein and fibre at different levels of nutritious DDS

The relationship between nutritious food groups consumed (DDS) and the mean truncated NARs of selenium, iodine and vitamin B12 is shown in figure 4.3. The mean selenium and vitamin B12 NARs are significantly correlated with nutritious DDS (see table 4.10). Vitamin B12 NAR does not go below an NAR of 0.8 at any number of nutritious food groups consumed. Selenium intake is lowest when only eight nutritious food groups are consumed, but the strength of this value is low as only one participant consumed eight nutritious food groups. Iodine intake is highest when nine nutritious food groups were consumed, but never reaches a NAR of one.

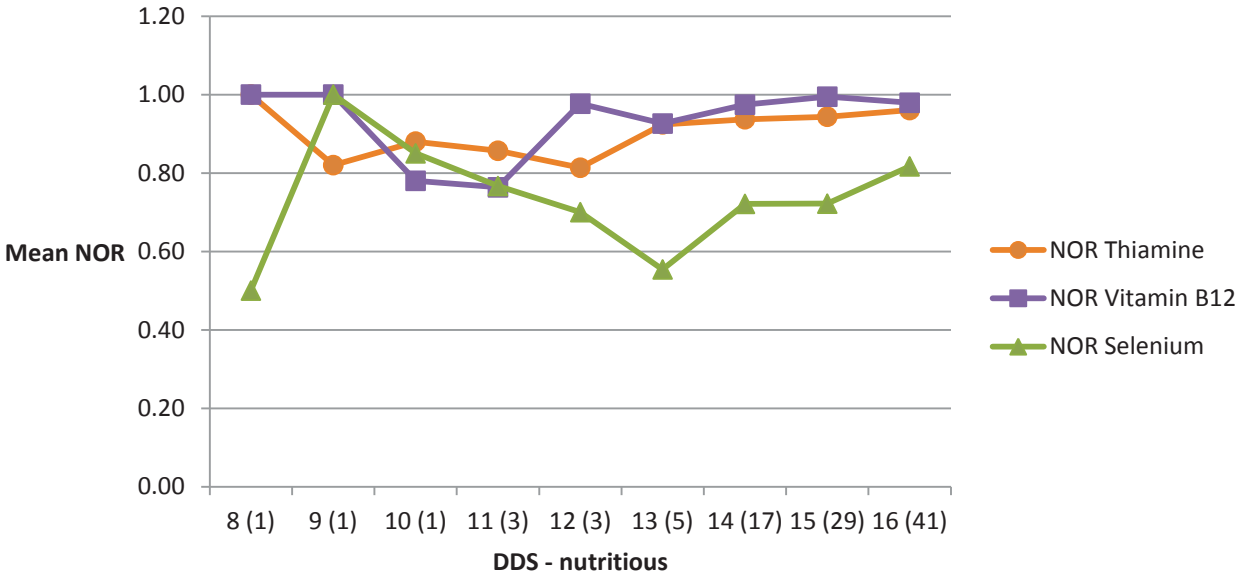


NAR, nutrient adequacy ratio; DDS, dietary diversity score

Figure 4.3 – Mean truncated NARs of selenium, iodine and vitamin B12 at different levels of nutritious DDS

4.5.4 Relationship between the number of nutritious food groups consumed and optimal nutrient intake

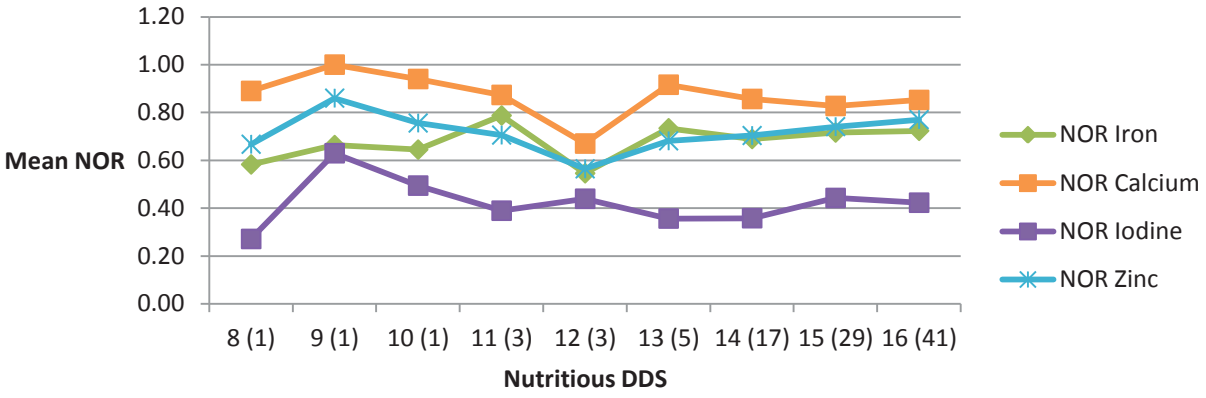
The relationship between the number of nutritious food groups consumed (DDS) and the mean truncated NORs of thiamine, vitamin B12 and selenium are shown in figure 4.4. The mean thiamine, vitamin B12 and selenium NORs are significantly correlated with nutritious DDS (see table 4.11). Thiamine NOR increase as the number of nutritious food groups consumed increased from 12 to 16. Selenium NOR is highest when nine nutritious food groups are consumed. Vitamin B12 NOR increase as the number of nutritious food groups consumed increased from 13 to 15.



NOR, nutrient optimisation ratio; DDS, dietary diversity score

Figure 4.4 – Mean truncated NORs of selenium, iodine and vitamin B12 at different levels of nutritious DDS

The relationship between the number of nutritious food groups consumed (DDS) and the mean truncated NORs of iron, calcium, iodine and zinc are shown in figure 4.5. The NOR for iodine never gets higher than 0.70 at any number of nutritious food groups consumed. Calcium NOR is highest when nine nutritious food groups are consumed.



NOR, nutrient optimisation ratio; DDS, dietary diversity score

Figure 4.5 – Mean truncated NORs of iron, calcium, iodine and zinc at different levels of nutritious DDS

4.5.5 Investigating the relationships between nutrient adequacy/optimisation and food variety of specific food groups

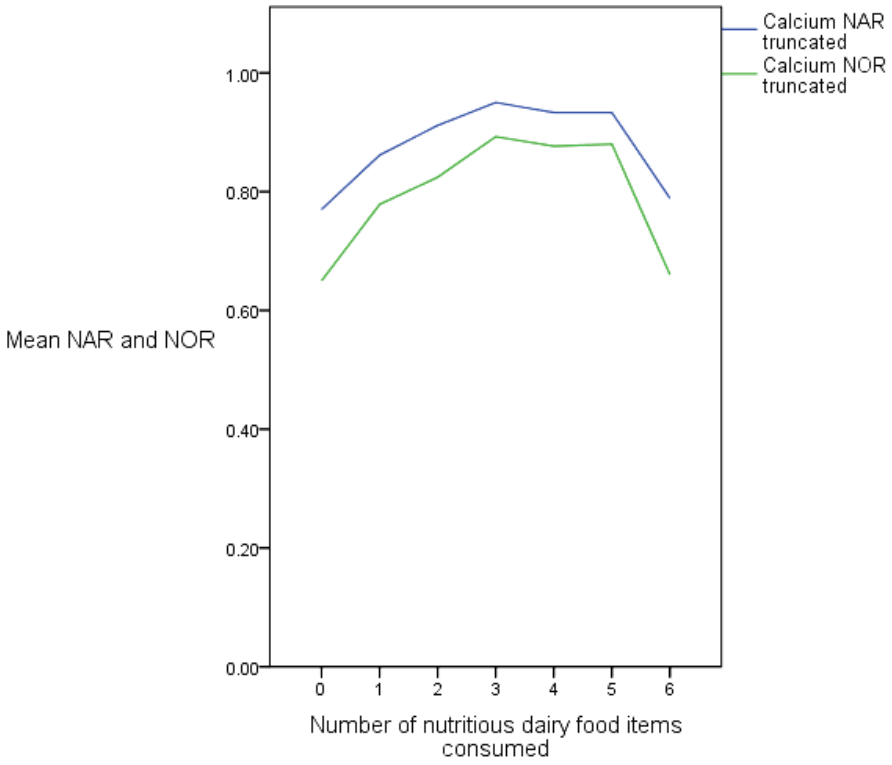
Table 4.12 shows the correlations between the number of calcium-containing food groups and the intake of calcium, and the calcium NAR and NOR. When nutritious calcium-containing foods items were separated into dairy products and cheeses, there was a significant correlation found between the number of dairy products and calcium intake, NAR and NOR, but not for cheeses.

Table 4.12 – Correlations between FVS of calcium-containing food groups and calcium intake, NAR and NOR

	FVS of calcium-containing food items			
	Dairy products (nutritious) FVS		**Cheese FVS**	
	Spearman's correlation (r_s)	Significance (two-tailed) (P)	Spearman's correlation (r_s)	Significance (two-tailed) (P)
Calcium intake	.231	0.020*	-.114	0.257
NAR calcium	.212	0.034*	-.181	0.070
NOR calcium	.218	0.028*	-.134	0.183

* Statistical significance at P<0.05

In figure 4.6 the mean NAR and NOR of calcium are shown at varying intakes of nutritious dairy products foods items. The NAR and NOR of calcium increase from one to three food items, and do not further increase beyond this.



NAR, nutrient adequacy ratio; NOR, nutrient optimisation ratio

Figure 4.6 – The NAR and NOR of calcium at different levels of nutritious dairy food items

Table 4.13 shows the correlations between the number of vitamin B12-containing food groups and the intake of vitamin B12, and the vitamin B12 NAR and NOR. Increasing the number of meat, poultry and fish and seafood food items consumed strongly relates to an increase in vitamin B12 intake, as well as increased vitamin B12 NAR and NOR. On their own, egg, dairy product and cheese groups FVSs did not correlate with vitamin B12 (not shown in table).

Table 4.13 – Correlations between FVS of vitamin B12-containing food groups and vitamin B12 intake, NAR and NOR

	FVS of vitamin B12-containg food items					
	Meat FVS		**Poultry FVS**		**Fish and seafood FVS**	
	Spearman's correlation (r_s)	Significance (two-tailed) (P)	Spearman's correlation (r_s)	Significance (two-tailed) (P)	Spearman's correlation (r_s)	Significance (two-tailed) (P)
Vitamin B12 intake	.258	0.009**	.291	0.003**	.411	0.000**
NAR vitamin B12	.299	0.002**	.282	0.004**	.216	0.030*
NOR vitamin B12	.329	0.001**	.327	0.001**	.273	0.006**

* Statistical significance at P<0.05

**Statistical significance at P<0.01

4.5.6 MAR and MOR at different levels of dietary diversity and food variety

Cross-tabulation of DDS and FVS was conducted to investigate the extent to which food item and food group counts are able to determine the MAR and MOR. Table 4.14 shows the mean MAR scores at different counts of nutritious food groups and nutritious food items. When only 0-20 foods were consumed from only eight food groups the MAR was 0.90, but when 81-100 foods were consumed from 16 groups the MAR improved to 0.96. Only one participant consumed each of these food items and food groups reducing the strength of these values. There is a trend showing that most participants ate from 41-60 or 61-80 individual foods and 15 or 16 food groups, and that these participants have an MAR of 0.95 or 0.94 (as shown in the blue shaded area).

Table 4.14 – Mean MAR scores at different levels of nutritious DDS and FVS

	Nutritious FVS					
Nutritious DDS	**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)	

MAR, mean adequacy ratio; FVS, food variety score; DDS, dietary diversity score

Table 4.15 includes the MARs when only discretionary food groups and discretionary individual food items are investigated. Increasing discretionary FVS and DDS provides a lower MAR. In participants that consumed 41-60 discretionary foods from nine discretionary food groups, the MAR was 0.89, compared to participants that ate only 0-20 discretionary foods from four food groups had an MAR of 0.99; however this was only achieved by two participants.

Table 4.15 – Mean MAR scores at different levels of discretionary DDS and FVS

	Discretionary FVS		
Discretionary DDS	**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)

MAR, mean adequacy ratio; FVS, food variety score; DDS, dietary diversity score

Table 4.16 provides the MORs at different levels of nutritious food groups and nutritious individual food items. There is a trend of increasing the number of nutritious food groups and food items with a corresponding increase in MOR. For example, participants that consumed 16 food groups and 61-80 food items, their MOR was 0.88 (n=12); but when only 41-60 food items were consumed from 16 food groups, the MOR was lower at 0.84 (n=22). Interestingly, there was no difference in MOR when DDS was either 15 or 16 and 41-60 food items were consumed. However, when only 21-40 food items were consumed from only 13 food groups, the MOR was 0.82 (n=4), and this MOR increases to 0.86 (n=4) when the number of food groups increased to 15.

Table 4.16 – Mean MOR scores at different levels of nutritious DDS and FVS

	Nutritious FVS					
Nutritious DDS	**0-20**	**21-40**	**41-60**	**61-80**	**81-100**	**101-120**
8	0.80 (n=1)					
9	0.84 (n=1)					
10		0.75 (n=1)				
11		0.81 (n=2)	0.87 (n=1)			
12		0.75 (n=1)	0.81 (n=2)			
13		0.82 (n=4)	0.88 (n=1)			
14		0.83 (n=7)	0.82 (n=8)	0.77 (=1)		0.84 (n=1)
15		0.86 (n=4)	0.84 (n=22)	0.76 (n=3)		
16		0.85 (n=4)	0.84 (n=22)	0.88 (n=12)	0.86 (n=3)	

MOR, mean optimisation ratio; FVS, food variety score; DDS, dietary diversity score

Table 4.17 shows the MORs at varying levels of discretionary food groups and discretionary individual food items. There is a trend of lower MOR at higher discretionary DDS and FVS, and a higher MOR at lower levels of discretionary DDS and FVS. For example, when nine discretionary food groups are consumed and 41-60 discretionary food items are consumed the MOR is 0.77 (n=6), but when the number of discretionary food groups consumed is reduced to six and discretionary food items to 0-20, the MOR rises to 0.83 (n=13).

Table 4.17 – Mean MOR scores at different levels of discretionary DDS and FVS

	Discretionary FVS		
Discretionary DDS	**0-20**	**21-40**	**41-60**
4	0.97 (n=2)		
5	0.79 (n=5)		
6	0.83 (n=13)	0.87 (n=1)	
7	0.86 (n=11)	0.83 (n=24)	
8	0.85 (n=4)	0.86 (n=24)	0.84 (n=1)
9		0.83 (n=10)	0.77 (n=6)

MOR, mean optimisation ratio; FVS, food variety score; DDS, dietary diversity score

5. Discussion

The main aim of this study was to develop and validate a dietary diversity questionnaire (DDQ) for use in New Zealand women. Much of the previous research on dietary diversity has been conducted in developing countries, where poor dietary diversity is a major problem. In developing country settings, it has been proven that increasing the variety of diets can improve nutrient intake, energy intake, food security and health outcomes (Ruel, 2003). Standardised methods to assess dietary diversity in developing countries are present (FAO, 2011). However, there has been minimal research conducted on dietary diversity in developed countries. The effect of high food accessibility and availability, especially of discretionary foods, in a developed country had yet to be explored. In this study a DDQ was developed specifically for a subsample of New Zealand women, and was validated against four-day weighed food records. To our knowledge, this study was the first to investigate dietary diversity and its ability to reflect nutrient intakes in New Zealand women, and is one of few dietary diversity studies conducted in developed countries.

5.1 Dietary Diversity and Food Variety in the Subsample of New Zealand Women

5.1.1 Profile of subsample

A total of 101 women were included in the subsample. The mean ± SD age was 32 ± 7 years, and they were New Zealand European (82.2%), Māori (10.9%) and Pacific (6.9%) ethnicities. Most women (68.3%) had a normal (BMI 18.5-24.9 kg/m^2). This subsample of women may not be a representative sample, as the average portion of New Zealanders that are overweight or obese is 64% (BMI >25 kg/m^2) (Ministry of Health, 2012).

5.1.2 Consumption of nutritious food items and food groups – developed vs. developing country settings

The median nutritious FVS was 49 (41, 59). As per previous research on the categorisation of the number of food items consumed into low, medium and high categories (Matla, 2008), this subsample of women consumed a medium number of food items (30 – 61 food items). The range of nutritious food groups consumed was eight to 16 food groups, suggesting that some women in the subsample were missing out on quite a large number of food groups in their diet. Studies conducted in developing countries have shown food variety to be low; in Mali, the mean FVS over two to three days was 20.5, (Hatloy *et al.*, 1998), in South Africa the FVS over one day was 5.5 (Steyn *et al.*, 2006), and in another South African study the mean FVS over a week period was extremely low at 3. Therefore, variety of nutritious food items in a developed

country setting is greater than in the developing country setting, but interestingly it is still not high.

The average nutritious DDS in the subsample of women was 15, from a possible 16 nutritious food groups. The intake of nutritious food groups in this study is high compared to other studies, however a much higher number of nutritious food groups were included (16 nutritious food groups in total), compared to some other studies where only eight or nine food groups have been used (Hatloy *et al.*, 1998; Steyn *et al.*, 2006). However, one study conducted on Iranian adolescents used 23 nutritious food groups, and even with this high number of groups available the mean DDS was still only 6.25. Consequently, it can be concluded that, in this research study, the subsample of women consumed a high number of nutritious food groups.

5.1.3 Average number of food items and food groups consumed

The median (25, 75 percentile) number of food groups consumed was 23 (21, 23) and median number of food items consumed was 75 (61, 87). These scores include nutritious and discretionary food items and food groups. A dietary diversity study conducted on three population groups of women from different areas in Vietnam also included discretionary food items and food groups and food groups in their diversity indicators (Ogle *et al.*, 2001). The mean number of food items eaten by the three groups over seven days were 16, 17 and 19, and the mean number of food groups consumed was were 8, 8 and 10. Majority of other dietary diversity studies have not included discretionary food items and food groups in their diversity indicators. Therefore, overall dietary diversity is high in this subsample of New Zealand compared to women in a developing country.

5.1.4 Introducing measurement of discretionary food items in dietary diversity assessment in a developed country setting

The mean ± SD discretionary FVS was 25.61 ± 9.99, out of a possible 94 discretionary food items. Therefore, in addition to the average of 49 nutritious food items the subsample of women consumed in a week, women were consuming around another additional 26 discretionary food items. This was consumed from an average of seven out of a possible nine discretionary food groups. This reflects New Zealand research, showing that there is high food availability and accessibility, particularly of unhealthy foods (Jenkin *et al.*, 2011). The DDQ was able to identify this high availability and accessibility of foods, including discretionary foods, which had not been assessed in a developing country setting in previous dietary diversity research.

5.2 Food Patterns of the Subsample of New Zealand Women

5.2.1 Commonly consumed food items and food groups

The majority of foods from the top 25 food consumption list were mainly nutritious, with 20 of them from nutritious food groups. Interestingly, five discretionary food items made the list, including water; tomato sauce, BBQ sauce, sweet chilli sauce, mustard sauce etc; chocolate; salt; and wine. Three protein-containing food items and four fruit and vegetable food items were included in the top 10. Only one starch-based item made the top 25 most commonly consumed food items list. This differs to the top 10 food items consumed by South African women, where five of the top 10 food items consumed were carbohydrate-based (Oldewage-Theron & Kruger, 2011). In developing countries, diets consist largely of starchy staples, with minimal consumption of fruits, vegetables and animal products (Ruel, 2003). In contrast fruits, vegetables and animal products, as well as discretionary foods, are more commonly consumed compared carbohydrate-based foods in a developed country setting, based on findings from this subsample of New Zealand women.

In this study only one dairy-based food item made the top 25 food consumption list, which was hard cheese. Conversely, the New Zealand Adult Nutrition Survey found that milk is the major individual food item that contributes to calcium intake (27% of calcium intake) (Ministry of Health and Otago of University 2011). This suggests that people who drink milk drink it in large quantities, however not many women drink milk, as is seen in this subsample of women.

Four items from the vitamin A-rich fruits and vegetables food group made the top 25 most commonly consumed food items, and the average number of vitamin A-rich food items consumed during the seven day period was 8.20. This may relate to the finding that only 12.1% of women in New Zealand have inadequate vitamin A (retinol equivalents) intake (Ministry of Health and Otago of University 2011). In South African women, the average number of vitamin A-rich food items consumed was 0.4 (Oldewage-Theron & Kruger, 2011). In developing countries vitamin A deficiency is common due to limited access to preformed vitamin A food sources and poverty (Coates *et al.*, 2010). In New Zealand the risk of deficiency is much lower, however, Pacific children and Māori males are at higher risk of inadequate intakes than other population groups within New Zealand (Ministry of Health, 2003b). According to the vitamin A NAR and NOR calculated, on average the women in this subsample were consuming adequate and optimal amounts of vitamin A.

There were only two out of the 25 possible food groups from which all participants consumed food from. They were both discretionary food groups: sauces, spreads and flavourings; and sweet snacks.

Nearly all women (99%) consumed food from the drinks food group. In New Zealand around 37% of adults consume three or more fruit drinks a week, and around 24% consume soft drinks or energy drinks three or more times a week (Ministry of Health and Otago of University 2011). In this subsample of women, 33% consumed normal soft drinks, and 41% consumed diet soft drinks, but it is unknown how many times during the seven day period they were consumed. In terms of alcoholic drinks, around 81% of participants consumed alcohol. Similar to findings from the National Nutrition Survey (Ministry of Health and Otago of University 2011), wine was the alcoholic beverage most commonly consumed.

About 74% of the participants consumed fish and seafood in the seven day period, which is much higher than the average New Zealander, for which only around 42% consume fish and seafood in a week period (Ministry of Health and Otago of University 2011).

5.3 Nutrient Intakes in the Subsample of New Zealand Women

5.3.1 Mean adequate and optimal intakes of micronutrients

The MAR for the NZ women was 0.94, which infers that on average 94% of 13 nutrient EAR were met. Previously MAR has been used to reflect nutrient adequacy and hence diet quality (FAO, 2011; Hatloy *et al.*, 1998). A MAR of 0.94 is high compared to other studies, for instance MAR values 0.77, 0.50 and 0.50 have been previously calculated (Oldewage-Theron & Kruger, 2011; Steyn *et al.*, 2006; Torheim *et al.*, 2004). These studies were based in developing countries, and the low MAR values suggested that participants were not meeting nutrient recommendations, and hence had poor diet quality. The result of a high MAR suggests that in this subsample of New Zealand women, they have adequate intakes of micronutrients and hence have higher quality diets compared to populations in developing countries.

The MOR in the subsample of New Zealand women was 0.84, and this implied that 84% of 13 nutrient RDIs were met. The MOR was used in this study to reflect optimal nutrient intakes, as a value of 1 would indicate 100% intake of each micronutrient. Therefore, nutrient intakes in this subsample of New Zealand women were not optimal. The women in this study on average consumed only a medium variety of nutritious food items. Perhaps if a high variety of nutritious food items (61 or more) were instead consumed, nutrient intakes would be greater and the MOR would be closer to 1. It is important to note here that RDIs exceed actual

nutrient requirements of healthy persons, as they were developed to accommodate the variation in absorption and metabolism of each nutrient (National Health and Medical Research Council, 1991; Truswell, Dreosti, English, Rutishauser, & Palmer, 1990). Therefore the RDIs may actually be too high for some women in this study, and hence MOR could be suggestive of recommendations not being met or low when they actually are being met. However, the RDI was used in the MOR calculation as it is more reflective of optimal nutrient intake, to cover variation in absorption and metabolism of nutrients, and reflect a setting where foods and consequently nutrients are highly available.

5.3.2 Adequacy of energy intake

A NAR was also calculated for energy, but was not included in the MAR calculation. The mean ± SD energy NAR was 0.77 ± 0.18. The energy NAR did not correlate with increasing DDS or FVS, showing that an increase in food items or food groups consumed is not related to an increase in energy intake. It has previously been suggested by Foote *et al.* (2004) that reducing dietary variety should be employed to help reduce energy intake to help reduce the risk of obesity. However the findings of this study suggest there is not a link between dietary diversity and increased energy.

Previous research suggests that people, particularly women and those with a high BMI, underreport their food intake (Gemming, Jiang, Swinburn, Utter, & Mhurchu, 2014; Livingstone & Black, 2003; Ministry of Health and Otago of University 2011). When compared with doubly labelled water technique (gold standard of energy expenditure measurement), it was found that a range of dietary assessment methods underreport energy intake (Scagliusi *et al.*, 2008). A large proportion of the participants (96%) in this study did not meet their estimated energy requirements as per the Schofield equation (Schofield, 1985), and the mean NAR for energy was a low value of 0.77. The women's food records may possibly be unreflective of their actual energy intakes. With the under-reporting of food and energy intake being a serious problem nutrition studies, the Goldberg method (Black, 2001) was used to assess energy intake in this subsample of women. A high proportion of women, seventy-six (75.2%) participants, were identified as under-reporters based on reported energy intake from the weighed four day food record. Other studies have identified under-reporting as low as 12.12% (Beck *et al.*, 2012) and as high as 71.4% in others (Beck, Mitchell, Foskett, Conlon, & von Hurst, 2013). No women were excluded from the study following this finding.

5.3.3 Nutrient adequacy of protein, fat and carbohydrate

A NAR was calculated for protein intake, but again not included in the MAR calculation. Protein NAR was one at all levels of nutritious DDS, indicating that protein intake is adequate in all women regardless of the number of nutritious foods consumed. While protein deficiency and protein-energy malnutrition (PEM) is common worldwide in children and adults (Stephenson, Latham, & Ottesen, 2000), in developed countries like New Zealand, PEM is mostly only seen alongside disease states and in the elderly. It has been shown previously that New Zealand women generally meet their protein intake, with only 2.3% having inadequate protein intakes (Ministry of Health and Otago of University 2011). A protein NAR of one at all levels of DDS may be explained by the fact that there is wide distribution of protein among food groups, with protein being found in a wide range of food groups, such as meat, poultry, fish, cereals and cereal-based foods, milk and dairy products, and smaller amounts in vegetables (National Health and Medical Research Council, 2006). It can be concluded that in this group of women, protein requirements in terms of recommended amount of grams to consume daily are met regardless of the number of nutritious food groups consumed.

As a percentage of energy intake, it is recommended that women over 19 years should consume 15-25% of their energy from protein (National Health and Medical Research Council, 2006). The average percentage of protein intake contributing to total energy intake was 18.11% ± 3.94%. However, the percentage of women in the study not meeting this recommendation was 20.8%. Therefore, although they met the recommended amount of protein in grams does not mean they will have met their recommended amount of protein consumed in regards to the recommended percentage energy contribution of protein to total energy intake.

A NAR for total fat and saturated fat could not be calculated as there is no recommendation for the suggested amount in grams of fat to be consumed. As a percentage of energy intake, it is recommended that women over 19 years should consume 20-35% of their energy from fat (National Health and Medical Research Council, 2006). A large proportion of women did not meet the recommendations for total fat and saturated fat contribution to total energy intake (46.5% and 82.2% of participants, respectively). The mean intake ± SD of saturated fat intake as a percentage of total energy intake was 12.65 ± 3.54%, suggesting that women did not meet the acceptable macronutrient distribution range (AMDR) of 8-10% for saturated and trans fat because they consumed too much saturated fat. This is similar to the National Nutrition Survey results which found that on average, in New Zealand, adults saturated fat intake contributed

13.1% to total energy intake (Ministry of Health and Otago of University 2011). In this research study the recommendation for polyunsaturated fat intake as a percentage of overall energy intake (6-10% of total energy intake) was not met by a large proportion of participants (68.3%), and monounsaturated fat intake by a smaller proportion (22.8%). The data provided from the food records show that in this subsample of women, high proportions of women were consuming excess total and saturated fat. Most participants (58) consumed two or three food items from the nutritious food group oils and fat (see table 4.3). However, many participants also consumed three food items from the takeaway and fast-food food group (23 participants), one or two food items from the savoury snacks food group (48 participants), and four or five food items from the sweet snacks (45 participants) (see table 4.4). Perhaps the variety of foods consumed from these discretionary food groups contributed to high intakes of fat and saturated fat.

Many women in the subsample (70.3%) did not meet the recommended carbohydrate intake of 45-65% of total energy from carbohydrate (National Health and Medical Research Council, 2006). The average intake of sugar as a percentage of total energy intake was 20.71 ± 5.36%, which is high considering the recommended intake is ≤15% for women over 19 years (Ministry of Health, 2003a). A large proportion of women (80.1%) did not meet this recommendation. No food items from the sweet snacks food group made the top 25 food list, however, the sweet snacks food group was one of only two food groups which all participants consumed food items from over the seven day period. Perhaps this is a contributor to high sugar intakes.

5.3.4 Adequacy and optimisation of micronutrients

With NAR values reaching one or more as evidence, all micronutrients, except for iodine, were consumed in adequate amounts. The New Zealand adult population was previously deemed as mildly iodine deficient which was mainly due to low soil concentrations of iodine, and consequently mandatory fortification of bread with iodised salt was implemented in 2009 (Ministry of Health and Otago of University 2011; Skeaff, McLean, Mann, & Williams, 2013). In terms of optimal iodine intake, 96% of participants were not eating the RDI. In extreme cases, iodine deficiency can cause irreversible brain damage (Mason *et al.*, 2001). Iodine deficiency can also lead to hypothyroidism, goitre and mental and physical development (National Health and Medical Research Council, 2006). The major dietary source of iodine comes from marine sources, however in New Zealand bread and salt are also sources due to iodine fortification. Nearly all participants consumed bread (99%), salt was consumed by 71% of participants, and fish and seafood was consumed by about 74% of participants. Although the mean ± SD for the

number of fish and seafood food items consumed in a week was 1.92 ± 1.12, about half of the participants consumed either none or only one fish and seafood item (see table 4.3). Inclusion of fish and seafood food items in the diet be a useful strategy to increase iodine intake and consequently improve iodine status. Additionally, a DDQ could be used to assess iodine intake through measurement of the number of seafood items consumed.

Nutrient intakes were adequate but not optimal (NOR below one) for iron, calcium and zinc. However, the mean calcium NOR was very close to one at 0.95, and it has been suggested that the calcium recommendations are high considering calcium is only one of many factors that affect bone health (Ministry of Health and Otago of University 2011). Conversely, the MOR for iron and zinc were quite low, at 0.74 and 0.77, respectively.

For some nutrients, it is more beneficial for health to consume a low amount, including saturated fat, sugar and sodium (Ministry of Health, 2003a). Therefore, for these nutrients it is more beneficial to have a NAR/NOR values below one. The mean ± SD NAR for sodium was 2.75 ± 1.24, showing that sodium intake is on average 2.75 times higher than the RDI. High sodium intakes can lead to hypertension, a major risk factor for cardiovascular and renal diseases (National Health and Medical Research Council, 2006). With salt being the 22nd most consumed food item out of a possible 237 food items in this subsample of women, and the consumption of 26 discretionary food items during a week, this could be contributing to high sodium intakes in this subsample of women.

5.3.5 MAR and MOR at different levels of dietary diversity and food variety

The investigation of MAR and MOR at different numbers of food items and food groups found that most participants consumed 41-80 nutritious food items from 15 or 16 nutritious food groups. Only one participant consumed between 101 and 120 nutritious food items in a week. This participant ate from 14 nutritious food groups and had a high MAR of 0.97 and MOR of 0.84. However, there was also one participant who consumed only 0-20 nutritious food items, from only 9 nutritious food groups, and there was very similar to the participant with high DDS and FVS, with a MAR of 0.98, and a MOR of 0.84. These indicators of dietary quality suggest that it is the selection of food items and food groups consumed that is important, rather than just increasing the number of food items and food groups consumed. While this may be the case, this was only comparing two participants, and a greater number of participants would be needed to increase the strength of this proposed idea around importance of selecting food items and food groups.

The investigation of MAR and MOR at different numbers of discretionary food items and food groups found that most participants consumed 0-20 discretionary food items from seven or eight discretionary food groups. There was a trend showing that as the number of discretionary food items and food groups consumed increased, the MAR and MOR decreased. This would be expected as discretionary food items are generally micronutrient-poor due to refined sugars and oils (Cordain *et al.*, 2005; Xyris Software, 2012) and subsequently would not contribute to nutrient intakes or to diet quality.

5.4 Relative Validity of the DDQ

5.4.1 Comparison of dietary diversity measures between two different dietary assessment methods

The relative validity of the developed DDQ was determined by comparing sets of dietary diversity measures (dietary diversity score (DDS) and food variety score (FVS)) calculated independently from the DDQ and the food record. The number of food items consumed from each food group was compared between the DDQ and food record. It was found that for 15 of the total 25 food groups, the estimated food group-specific FVSs were similar, with FVSs for each food group only varying around one to three food items only between the DDQ and food record. All food group-specific FVSs from each food group, except for two food groups (discretionary breads, cereals and starchy vegetables; and vitamin A-rich fruits and vegetables), from the DDQ and food record were significantly correlated. This provides evidence for the ability of the DDQ to assess the number of food items from each food group consumed in the same way a food record does. After adjusting the food record's dietary diversity measures (DDS and FVS) for the difference in time periods assessed, statistical analysis also showed that that sets of dietary diversity measures between the DDQ and food record were correlated. This also suggests that the ability of the DDQ to measure dietary diversity is similar to that of the four-day weighed food record, the gold standard dietary assessment method (Gibson, 2005). Other dietary diversity studies have used validation techniques where dietary diversity measures are compared with validation scores that reflect nutrient intake (Hatloy *et al.*, 1998; Oldewage-Theron & Kruger, 2011; Steyn *et al.*, 2006), but they do not provide another set of comparable dietary diversity measures like in this study. By comparing DDQ-generated dietary diversity measures with food record-generated dietary diversity measures, the performance of the DDQ to actually measure the number of food items and food groups could be determined.

5.4.2 Ability of DDQ to reflect nutrient adequacy

Similar to other dietary diversity studies, this research used validation techniques where dietary diversity measures were compared with nutrient validation scores. This was done to investigate the relative validity of the DDQ to determine whether it could reflect adequate micronutrient intakes. Significant correlations were seen between the nutritious DDS and the mean adequacy ratio (MAR) ($P<0.05$), which suggests that the likelihood of participants consuming the EAR of the 13 micronutrients investigated increases as the number of nutritious food groups consumed increases. From this it can be concluded that the measurement of nutritious food groups consumed is able to reflect whether or not the diet is adequate in nutrients. Interestingly, there were no significant correlations seen between the nutritious FVS and the MAR. This suggests that it is the number of nutritious food groups that are consumed that is more important than the number of nutritious food items consumed. The number of food items and food groups used in dietary diversity assessment is different across different studies due to differences in culture, population and location (FAO, 2011). Similar to the finding in this study, another study using nutrient validation scores to assess the ability of dietary diversity measures to evaluate nutrient adequacy also found that although both correlated to MAR, DDS (food groups) was a stronger determinant of MAR than FVS (food items) (Hatloy *et al.*, 1998). On the other hand, in another study FVS was a stronger determinant of MAR than DDS (Torheim *et al.*, 2004). Both these studies used nearly the same number of food items (75 and 76), however the latter study used 10 food groups and the former used only eight food groups. Therefore, perhaps the number of food groups used in the analysis affects the strength of the dietary diversity measures to reflect MAR. Dietary diversity indicators have better performance/ability to measure micronutrient adequacy when there is greater disaggregation of food groups (Arimond *et al.*, 2010). In the analysis of the results of this study, the food groups were largely disaggregated to compensate for the highly varied diet of a developed country, with a total of 25 food groups being used in the final analysis. In a developed country setting, this large number of food groups was able to reflect the nutrient adequacy of diets.

The relationship between DDS and individual nutrients was also considered. As the number of nutritious food groups increased, the nutrient adequacy ratio (NAR) for vitamin B12 and selenium increased significantly. Although the NAR of other nutrients did not increase as nutritious DDS increased, this could be explained by the distribution of these nutrients over different food groups. For example, the calcium NAR was not significantly correlated to nutritious DDS. Calcium is predominantly and naturally found in dairy products and cheese

(National Health and Medical Research Council, 2006). Conversely, vitamin B12 is in a greater range of food groups, including meat, poultry, fish, eggs, dairy products and cheese (National Health and Medical Research Council, 2006). Therefore, as the number of nutritious food groups increased, calcium intake would not necessarily continue to rise in parallel, as it is only predominantly in two food groups. Although cheese was one of the top 10 food items consumed in this subsample of women, its calcium content is not as high as the calcium content of milk (Sivakumaran *et al.*, 2013). On the other hand, vitamin B12 may be more likely to simultaneously rise with the number of nutritious foods groups as it is found in a greater number of food groups.

5.4.3 Ability of DDQ to reflect nutrient optimisation

As part of the aim of this study to assess dietary diversity in a developed setting, new and novel validation scores were developed, specifically the nutrient optimisation ratio (NOR) and mean optimisation ratio (MOR). These were based on nutrient intakes meeting the RDI rather than the EAR. The RDI provides a recommendation based on the nutrient level needed to meet nearly all (97-98%) healthy individual's nutrient requirements and therefore usual intake at or above this level has a low probability of being inadequate (National Health and Medical Research Council, 2006). Hence, RDI was used as a guide for optimisation of nutrient intakes, compared to the EARs which are recommendations based on nutrients levels needed to meet only half the healthy individual's nutrient requirements. In a developed country where food is highly accessible and available to people, it was assumed that the RDI for micronutrients were more likely to be met, and hence the RDI could be used in a nutrient validation score to represent optimal nutrient intake. Analysis was conducted between MOR and the number of nutritious food groups consumed to determine whether the DDQ could accurately reflect optimal nutrient intakes. Significant correlations were seen between the nutritious DDS and the MOR ($P<0.01$), but not between nutritious FVS and MOR. This proposes that the likelihood of meeting the RDI increases as the number of nutritious food groups consumed increases, but not as the number of nutritious food items increases. The outcome here is that the DDQ has relative validity in terms of being able to measure the number of nutritious food groups consumed and this measurement being able to reflect optimal micronutrient intakes.

The DDQ and its measurement of the number of nutritious food groups consumed was able to reflect optimal nutrient intake for some micronutrients in particular in this subsample of women. The NOR of thiamine, calcium and selenium were significantly correlated with the intake of nutritious food groups. This suggests that as the number of nutritious food groups

consumed increased, the likelihood of consuming optimal amounts of thiamine, calcium and selenium also increased.

5.4.4 Dietary diversity measurement compared to other markers of diet quality

The dietary diversity measures in this study were able to reflect diet quality through evaluation of adequate micronutrient intakes and also through the evaluation of optimal micronutrient intakes, which were introduced to address the developed country setting. In addition, the developed country setting with high food availability, it is important to focus on excess intakes of energy dense foods (discretionary foods) to address imbalances in the variety of food consumed. Therefore, unlike previous dietary diversity studies, this study captured and investigated both nutritious and discretionary dietary components. The main focus was still on desirable nutrients for the DDQ validation, but the unwanted overconsumption of saturated fat, sugar and sodium and consumption of discretionary food items and food groups were also investigated. This meant the dietary diversity measures in this study possessed a similar element to other scores of diet quality such as the Diet Quality Index (DQI) (Drewnowski *et al.*, 1997) and the Healthy Eating Index (HEI) (Foote *et al.*, 2004) which incorporate unwanted dietary components. The DQI, for example, assigns points based on whether diets follow the US dietary guidelines around fat, cholesterol, sodium and carbohydrate intakes. If the diet contains less than 30% of energy from fat then it is given a point, and if less than 10% of energy comes from saturated fat then other point is awarded, and so on (Drewnowski *et al.*, 1997). The downfall with such scores is that they are constructed from quantitative dietary intake, which unfortunately is expensive and time-consuming to collect and analyse (Black, 2001; FAO, 2011; Gibson, 2005). The benefit of the DDQ is that it does have relative validity in its ability to measure dietary diversity and provide an estimate of diet quality, it is quick and easy to complete and it provided some intriguing information on food group patterns in this subsample of New Zealand women.

6. Conclusion

6.1 Gap in Research and Aims of Research

Dietary diversity or dietary variety is the count of food items and/or food groups consumed over a defined period (Ruel, 2003). Globally, dietary diversity is recommended as part of a healthy diet (Department of Health. Directorate of Nutrition, 2007; Ministry of Health, 2003a; National Health and Medical Research Council, 2013; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2010). Research on dietary diversity in a developed country setting is minimal and the effect of high food accessibility and availability, especially of energy poor and nutrient dense foods, needed to be explored.

To our knowledge, there has been no research on dietary diversity in New Zealand, a developed country. Therefore, the aim of this study was to develop and validate a dietary diversity questionnaire (DDQ) that is suitable for use on New Zealand women aged 16-45 years of age with Māori, Pacific or New Zealand European backgrounds. The relative validity of the DDQ to accurately reflect the adequate and optimal nutrient intakes in a subsample of women was investigated.

6.2 The Main Findings of the Research

The main finding of this research was that the developed tool, the dietary diversity questionnaire (DDQ), had relative validity in its ability to assess dietary diversity and reflect adequate and optimal micronutrient intakes.

Two validation techniques were used in this study. The first involved the calculation of dietary diversity measures from the DDQ and comparing them with dietary diversity scores calculated from the food records. After adjustment of food record scores to align time periods covered by both sets of scores (seven days), it was shown that the dietary diversity scores were similar and hence the DDQ was able to measure dietary diversity similar to the food records. This indicated relative validity of the DDQ in its ability to measure dietary diversity.

The second method involved investigation of associations between dietary diversity measures from the DDQ and nutrient validation measures to represent diet quality developed from the food record. The nutritious dietary diversity score (DDS) was significantly correlated with the measures of diet quality, nutrient adequacy and optimisation ratios, indicating that the DDQ had relative validity in its ability to reflect diet quality.

Following the conclusion that the DDQ was relatively valid, dietary diversity in the subsample of women were investigated. The average number of food groups consumed was 23, and 15 of these were nutritious food groups. The average intake of nutritious food items was 49, and this was classified as medium food variety (Matla, 2008). This was reflected by the mean optimisation ratio (MOR) of 0.84, where a value of one reflects 100% intake of RDI for 13 micronutrients. Theoretically, if the intake of nutritious items was increased to 61 or more food items to be classified as high food variety, this could correspond with a MOR that is closer to great and more optimal micronutrient intakes.

To address assessment of dietary diversity in a developed country, the DDQ also measured intake of discretionary food items and food groups. In addition to the 15 nutritious food groups consumed, 7 discretionary food groups were consumed on average. An additional 26 discretionary food items were consumed on top of the 49 nutritious food items consumed. Compared to dietary diversity in developing countries where intake of food items consumed over a week period has been reported as low as three (Oldewage-Theron & Kruger, 2011), the intake of food items in this subsample of New Zealand women was high.

The results of the study show that the DDQ is a relatively valid tool for the assessment of dietary diversity and for the evaluation of adequate and optimal nutrient intakes.

6.3 Strengths

Dietary diversity is low in deprived populations in developing countries (Mirmiran *et al.*, 2004; Oldewage-Theron & Kruger, 2011; Ruel, 2003; Steyn *et al.*, 2006). Research on dietary diversity has been largely based on populations in developing countries, rather than developed countries, due to this lack of dietary diversity. A strength of this study is that it contributes internationally to the few dietary diversity studies conducted in developed country settings.

This is the first study to design a DDQ for use in a developed country setting. Dietary diversity has previously been assessed by a range of dietary assessment methods, but only once with a dietary diversity questionnaire (DDQ) and this was in a developing country setting (Matla, 2008). There is consensus and consistency on the measurement and validation of dietary diversity in developing countries (FAO, 2011; Steyn *et al.*, 2006), but not in developed countries. This study contributes to techniques and methods available for dietary diversity measurement and validation in developed countries.

This DDQ not only has the ability to assess dietary diversity in women aged 16 – 45 years, but has the ability to reflect whether intakes of micronutrients are adequate and optimal, and hence can indicate diet quality. Although other dietary assessment methods can be used to assess dietary diversity, many of these methods have downfalls. For example they can be expensive to conduct, time-consuming to collect and analyse data from, require skilled interviewers, have high respondent burden, require high motivation, and can require high literacy skills (Black, 2001; FAO, 2011; Gibson, 2005). Dietary diversity questionnaires on the other hand are quick and easy tool for participants to complete without aid of an interviewer, and dietary diversity measures can be calculated by researchers relatively quickly. Additionally, guidelines have been developed in attempt to make dietary diversity measurement consistent (FAO, 2011). This DDQ was a valid tool for dietary diversity measurement and the evaluation of diet quality in a developed country setting.

Although the DDQ does not account for portion sizes consumed or indicate which food groups are included in the measures (Dixon *et al.*, 2001), this is an advantage to the tool as it makes it quick and easy to complete. Separate nutritious and discretionary food groups were included in the DDQ to overcome the issue of energy dense, nutrient poor foods being included in dietary diversity measures which would not be reflective of a 'healthy' diet. The intake of nutritious food items and food groups were able to indicate adequate and optimal micronutrient intake without portion size information.

Unlike previous dietary diversity studies, this study considered the consumption of non-nutritious, discretionary food items and food groups to be reflective of a developed country setting. This was beneficial in assessing what effect the high availability and accessibility of unhealthy foods in New Zealand (Jenkin *et al.*, 2011) had on dietary diversity in this subsample of women.

For the analysis of dietary diversity, the number of food groups included was greater than the number of food groups included in the DDQ. The 14 food groups that were in the DDQ were disaggregated to 25 food groups. This was because dietary diversity indicators have better ability to reflect micronutrient adequacy when there is greater disaggregation of food groups (Arimond *et al.*, 2010). All the same food items were still included; there was just a greater break-down of food groups. This is a strength of the DDQ, that the number of food groups could be altered to investigate the association between dietary diversity and nutrient intake.

The four-day weighed food records were used as the reference dietary assessment method for the DDQ, which is beneficial as weighed food records have been labelled the "gold standard" dietary assessment method (Biro *et al.*, 2002). In addition, test and reference methods should have different sources of error to avoid similarities and agreement between methods where there is actually just a reflection of similar errors (Gibson, 2005; Willet, 1998). Weaknesses of the food record include high participant burden, alteration of usual eating patterns due to the recording process, and under-reporting of food intake, however a strength is that it does not require memory as participants should record food intake at time of consumption (Biro *et al.*, 2002). In contrast, the DDQ has very low participant burden and eating patterns are not altered by the recording process, though it does require memory for its completion. These weaknesses provide different sources of error and hence suggest they were a good combination of dietary assessment methods for this validation study.

Dietary intake and hence micronutrient intake changes with changes in seasons (Gibson, 2005; Serra-Majem *et al.*, 2009), and dietary data collection for this study occurred from August to 2013 to July 2014. This gave good coverage of dietary intake over a range of seasons and hence reflects intake on average, rather than for example just for one or two seasons.

A requirement of validation studies is that dietary intake between genders be examined separately due to the differences in the way men and women responded to dietary assessment methods (Gibson, 2005; Johnson *et al.*, 1994). In this study only women participated which is a strength to the study as it adds power to the relative validity of the DDQ.

6.4 Limitations

A limitation of the study is that the DDQ was completed retrospectively with regard to a seven day period of food intake, and the weighed food record was completed for four days only. Although the periods that food intake was measured overlapped, they did not cover the same length of time. The dietary diversity measures calculated from the food record therefore needed adjustment to reflect intake over a seven day period to match the DDQ. Unfortunately, this may not have been accurate. However, food records completed up to seven days have reduced reliability due high participant burden, a consequent increase in recording error and change in usual eating habits (Lee & Nieman, 2003; Meyer *et al.*, 2013). Therefore, a four-day compared to a seven-day record could actually have been more reliable.

The placing of the food records may also have been a limitation in this study. In validation studies, it is suggested that the test method be administered before the reference method. This is to avoid increasing participant's awareness of their food intake and subsequent alteration of the way the test method is completed, which would then artificially improve accuracy of the test method (Gibson, 2005; Willet, 1998). In this study the DDQ was completed after the food records, hence the accuracy of the DDQ may have been artificially improved through completion of food records. However, test and reference methods need to cover the same period. Therefore, the DDQ needed to be conducted after the food record in this study to ensure they covered the same period.

Another limitation to this study was that some food records did not contain four full days of dietary intake or they were not completed to an adequate standard, e.g. not readable, values missing, and very poor detail of type and amount of foods eaten. Where possible, participants were contacted to gather further information about their food intake to allow the food records to be used. Additionally, some food records were not returned at all. Where participants did not complete or return their food record, their completed DDQ could not be used in the validation study, as the food record was the reference dietary assessment method for DDQ validation. Similarly, some participants completed and returned their food record but did not complete the DDQ online. These food records also needed to be excluded from the validation study.

The basal metabolic rate (BMR) was calculated for each participants using the Schofield equation (Schofield, 1985), however as physical activity levels were unknown a physical activity level of 1.7 was used for all participants. This may have over-estimated the BMR some participants, and hence under-estimated energy NAR. Furthermore, it was estimated that 75.2% of participants under-reported their food intake based on their energy intake to BMR ratio, even when a lower physical activity level of 1.55 was used in BMR calculation.

Another limitation of the study was that the pilot studies conducted as part of the DDQ development process were conducted on nutrition and dietetic university students. These students may have had higher education levels, higher general literacy skills and higher nutrition literacy compared to participants. Although the DDQ is very simple to complete, the understanding of the DDQ and its completion may possibly not have been observed during the pilot studies that was representative of the subsample of women included in the study.

After completion of food records and the DDQ by the participants, it became apparent that a few key food items were missing from the DDQ or some food items should have been listed differently. For example, dairy blend should have been listed in addition to margarine and butter; other grains such as wheat germ/bran, bulgur wheat and barley should have been included; and the takeaway and fast food groups list of food items should have been more specific rather than suggesting culturally-based takeaway options, as there are an extensive range of culturally-based takeaway foods and a large range of food items within each, and these were not all included in the DDQ.

Sensitivity and specificity analysis to determine the ability of DDS and FVS cut-offs to accurately reflect diet quality could not be conducted in this study. This was because too many participants consumed adequate and optimal micronutrients, meaning that regardless of the number of food groups consumed, nutrient intake was still adequate and/or optimal. Therefore the ability of different cut-off values of DDS and FVS to assess diet quality could not be assessed.

The subsample of women in this study was the first women to sign up for the Women's EXPLORE Study. The initial marketing strategy for this study was targeting women who were "interested in their health". Therefore, the women in this sample may be health-conscious, and not representative of the rest of the New Zealand population. In addition, people who volunteer for research can have different dietary habits than those who do not volunteer, for example volunteers have been shown to eat food regularly, eat breakfast and consume less takeaway foods compared to non-volunteers (Kim, Kim, & Hyun, 2004). Therefore, this sample may not be a reflective sample of other New Zealand women who were not eager to participate in the study.

While it is important to include only one gender in validation studies, this is also a limitation as it means the results of the study may not be able to be applied to men. Similarly, the subsample of women were predominantly New Zealand European and ages between 16 and 45 years, therefore the results may not be able to be applied to other ethnic groups and other age population groups living in New Zealand, for example Asian women or children.

6.5 Use of the Research Findings

The DDQ had the ability to accurately reflect dietary diversity and diet quality in this subsample of New Zealand women. With previous dietary diversity research having the ability to reflect household food accessibility, household food security, socioeconomic status and

health in developing contries (FAO, 2011; Hoddinott & Yohannes, 2002; Jansen *et al.*, 2004; Kant *et al.*, 1993; Ruel, 2003), it would be beneficial to investigate whether dietary diversity can also reflect such findings in a developed country. With high overweight and obesity rates in New Zealand (Ministry of Health, 2013), the DDQ could be used as a quick tool to assess micronutrient adequacy and dietary diversity, and explore how it is related to overweight and obesity. The DDQ could also be used by workers in the health setting as a quick and easy dietary assessment tool to estimate the quality of individual diets.

6.5 Recommendations for Future Dietary Diversity Studies

1. Further validation studies of the DDQ should be conducted in New Zealand in other population groups, for example in Māori and Pacific Island ethnic groups, in men, in older adults and in children.
2. Future research on dietary diversity in New Zealand should be conducted to examine associations between dietary diversity and health outcomes, such as overweight and obesity, diabetes mellitus, cancer and cardiovascular disease.
3. There should also be investigation of associations between dietary diversity and other factors such as household food accessibility, food security and socioecononmic status in New Zealand.
4. Recommended changes to the DDQ for future use in New Zealand include:
    a. Use a more specific list of food items in the take-away and fast-foods food groups, and avoid using generic culturally-based foods such as Thai or Chinese, under which a lot of food items are included.
    b. Ensure food items are included only once with the different options available listed beside each, for example fresh, dried, canned, frozen, pureed or whole options where suitable
    c. Include current popular and trending foods on the market
5. Recommendations for future dietary diversity validation studies include:
    a. Conduct food records alongside the DDQ in a pilot study. This would allow the early establishment of systems for decisions and assumptions that are made during the entry of food records into FoodWorks. Consequently, this would ensure there is consistency with data entry from the beginning when actual results are entered.
    b. Similarly, if food records were conducted alongside the DDQ in a pilot study, a system could be developed early for the calculation of dietary diversity measures

from the food records. This process would ensure consistency in data entry and also ensure all necessary food items are included in the DDQ.

c. If possible, conduct sensitivity and specificity analysis to determine the ability of DDS and FVS cut-offs to accurately reflect diet quality.
d. Use a FFQ to assess whether DDQ has the ability to assess usual intake.

6.6 Conclusion

The dietary diversity in this subsample of New Zealand women was high compared to populations in developing countries, but the intake of nutritious food items indicated only a medium food variety. The DDQ was a valid tool for the assessment of dietary diversity and evaluation of adequate and optimal nutrient intake.

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Appendix A: DDQ

Massey University

The EXPLORE Study

Dietary Diversity Questionnaire

Thank you very much for taking part in the EXPLORE Study.
We are extremely grateful for your time, effort and commitment!

If you have any questions, please contact EXPLORE staff on:
414 0800 (extn 41189) email: explore@massey.ac.nz or
AJ Hepburn 027 404 5351

Either fill out the paper questionnaire after the 7-day period and return it to us in the envelope provided

OR

Fill it out online after the 7-day period at:
http://www.surveymonkey.com/s/W5TYNTW

DIETARY DIVERSITY QUESTIONNAIRE

Please tick the foods you consumed during the past 7 days. You only need to tick a food once even if it was consumed several times.
For foods that require preparation (e.g. meat) consider all types of preparation and cooking methods. Also consider foods that can be eaten in fresh, frozen, dried or canned versions.

1. FLESH FOODS (MEAT, POULTRY, FISH)	YES	NO
Lamb or mutton (e.g. chops, leg, stewing meat, flaps, etc.)		
Beef (e.g. steak, mince, stewing meat, etc.)		
Pork (e.g. chops, fillet, leg, etc.)		
Hocks, pork bones, pig's head		
Other meats (e.g. venison, etc.)		
Offal, (liver, kidneys, heart etc.)		
Goat (meat)		
Chicken (e.g. whole, thighs, drumsticks, etc.)		
Chicken wings, nibbles		
Chicken offal (e.g. livers, hearts, giblets, chicken frames, etc.)		
Crumbed, battered chicken (e.g. chicken schnitzel, nuggets, etc.)		
Other poultry (e.g. turkey, duck, mutton-bird, etc.)		
Cured meat (e.g. ham, bacon, salami, etc.)		
Luncheon meats, all varieties		
Tinned meat (e.g. corned beef, etc.)		
Sausage, all varieties		
Meat patties		
Fish, fresh, white (e.g. hoki, snapper, flounder, etc.)		
Fish, fresh, brown or pink (e.g. salmon, trout, eel, etc.)		
Crumbed, battered fish (e.g. fish fingers, fish cakes, etc.)		
Tinned tuna, salmon		
Other tinned fish (e.g. sardines, mackerel, herring, etc.)		
Roe (e.g. caviar, fish eggs, etc.)		
Shell fish (e.g. mussels, oysters, scallops, clams, pipis, cockles, paua, kina, etc.)		
Crayfish, shrimp, prawns, crab		
Squid, calamari, octopus		
Whitebait		
Other		

2. EGGS	YES	NO
Eggs		

3. DAIRY PRODUCTS	YES	NO
Full cream milk (dark blue top)		
Low-fat milk (light blue top)		
Skim milk (green top)		
Milk with calcium added (yellow top)		
Evaporated milk, tinned, (unsweetened)		
Fermented milk (Buttermilk, etc.)		
Sweetened condensed milk		
Cream or sour cream		
Hard cheese (e.g. edam, tasty, etc.)		
Soft cheese (e.g. cottage, ricotta, camembert, etc)		
Processed cheese (slices or spread)		
Custard		
Ice cream		
Yoghurt, full fat		
Yoghurt, low fat		
Yoghurt drink		
Dairyfood		
Other milks (e.g. soy milk, rice milk, almond milk, etc.)		
Other		

4. BREADS, CEREALS AND STARCHY VEGETABLES	YES	NO
Rice, all varieties (e.g. long grain, white, brown Basmati, Jasmine, etc.)		
Bread, white		
Bread, whole-wheat, whole-grain, wheat-meal, multi-grain, etc.		
Fruit bread or buns		
Specialty breads (e.g. croissant, panini, focaccia, pita, muffin splits, crumpets, etc.)		
Wraps		
Māori bread (rewena), doughboys		

Pasta (e.g. macaroni, spaghetti, penne, etc.)		
Rice vermicelli (rice noodles)		
Instant noodles (two-minute noodles, all varieties, e.g. Maggi, Fantastic, etc.)		
Instant flavoured pasta packets (e.g. macaroni and cheese, chicken and mushroom, etc.)		
Quinoa		
Couscous		
Dumpling (e.g. pork dumpling, red bean dumpling, etc.)		
Large savoury muffins (e.g. cheese etc.)		
Scones		
Crackers (e.g. cream crackers, vita wheat, etc.)		
Porridge (e.g. rolled oats, oat meal, etc.)		
Sweetened breakfast cereals (e.g. Coco Pops, Fruit Loops, Nutri-Grain, etc.)		
Unsweetened breakfast cereals (e.g. Cornflakes, Rice Bubbles, etc.)		
Bran flakes (e.g. All Bran, Special K Advantage, etc.)		
Wheat biscuits (e.g. Weet-Bix, etc.)		
Muesli, all varieties		
Liquid meal (e.g. Up and Go liquid breakfast, etc.)		
Potatoes		
Kumara (sweet potato)		
Taro		
Cassava		
Corn		
Green banana, plantain		
Swedes		
Yams		
Turnip		
Parsnip		
Other		

5. LEGUMES AND NUTS	YES	NO
Dried beans (e.g. kidney, sugar, red, butter, garbanzo, etc.)		
Canned beans (e.g. kidney, sugar, red, butter, garbanzo, etc.)		
Dried peas (green)		
Dried lentils (brown, red)		
Canned lentils (brown, red)		
Chick peas (e.g. in hummus, in falafels, etc)		
Tofu, tempeh		
Salted, flavoured nuts		
Nuts (e.g. pecan, walnut, almond, cashew, etc.)		
Peanuts		
Seeds (e.g. sunflower, sesame, poppy, pumpkin, etc.)		
Coconut flesh		
Other		

6. FRUITS (AND JUICES)	YES	NO
Apple		
Peaches, white		
Peaches, yellow		
Apricots		
Mango		
Pears		
Grapes		
Plum		
Lemon, lime		
Orange		
Mandarin		
Banana		
Pineapple		
Avocado		
Berries (e.g. blueberry, boysenberry, etc.) and cherries		
Strawberry		
Feijoa		
Kiwifruit		

Gooseberry		
Watermelon		
Melon, green or yellow		
Persimmon		
Guava		
Lychees		
Papaya/pawpaw		
Tamarilo/tree tomato		
Passion fruit		
Prunes, dates		
Raisins, sultanas, currants		
Other		

7. VEGETABLES	YES	NO
Onions		
Spring onions		
Leeks		
Cabbage		
Red cabbage		
Spinach, silverbeet, kale		
Puha		
Watercress		
Rhubarb		
Chinese greens (e.g. bok choy, pak choi, etc.)		
Brussel sprouts		
Taro leaves		
Carrots		
Beetroot		
Radishes		
Asparagus		
Celery		
Cucumber		
Squash (e.g. gem, butternut, etc.)		
Pumpkin		

Tomatoes		
Green beans		
Peas		
Cauliflower		
Broccoli		
Chili (red/green)		
Lettuce, all varieties		
Mushroom		
Courgette/zucchini		
Capsicum (green, yellow, orange, black)		
Capsicum, red		
Eggplant/aubergine		
Garlic		
Artichoke		
Other		

8. OILS AND FATS	YES	NO
Butter		
Clarified butter (e.g. ghee, etc.)		
Margarine, all varieties		
Margarine, all varieties, low fat or lite		
Lard (e.g. dripping, animal fat, etc.)		
Oil (e.g. olive, sunflower, canola, rice bran, etc.)		
Coconut cream (e.g. Kara, Fia Fia, etc.)		
Coconut milk (e.g. Kara, Ayam, Tropical, etc.)		
Other		

9. DRINKS	YES	NO
Juice (100% pure juice e.g. Ceres, Arano, etc.)		
Juice (<100% pure / imitation juice, e.g. Just Juice, McCoy, etc.)		
Imitation drinks (e.g. cordial, Raro, etc.)		
Soft drinks (e.g. Coke, Fanta, etc.)		
Diet soft drinks (e.g. Coke Zero, etc.)		
Flavoured milk (e.g. Milo, Nesquik, Primo, hot chocolate, milkshakes,		

Koko, etc.)		
Tea (e.g. Dilma, Twining's, etc.)		
Herbal tea (e.g. green tea, chamomile, etc.)		
Coffee, instant or brewed, with or without milk (e.g. flat white, espresso, etc.)		
Coffee-based drinks (e.g. latte, cappuccino, mochaccino etc.)		
Soups, instant, powdered (e.g. Cup a Soup, etc.)		
Energy drinks (e.g. Red Bull, Mother, etc.)		
Sports drinks (e.g. Powerade, Gatorade, etc.)		
Flavoured water (e.g. Mizone, h2go flavoured water, etc.)		
Water		
Other		

10. ALCOHOL	YES	NO
Beer, all varieties, commercial		
Home brewed beer (e.g. hop beer, aaleve, etc.)		
Cider (e.g. Monteith's crushed apple, Magners, etc.)		
Wine (red or white)		
Spirits (e.g. rum, brandy, whiskey, etc.)		
Kava		
RTDs (ready-to-drinks) (e.g. Vodka Cruisers, Archers, etc.)		
Other		

11. SAUCES, SPREADS AND FLAVOURINGS	YES	NO
Tomato, BBQ, sweet chilli, mustard sauce, etc.		
Mayonnaise, salad cream or creamy dressings (e.g. aioli, tartare, etc.)		
Salad dressing (French, Italian, etc.)		
Chutney, relish		
White sauce, cheese sauce		
Gravy, homemade		
Gravy, packet (e.g. Maggi roast chicken gravy, Royal brown gravy, pepper sauce, etc.)		
Soy sauce		
Fish sauce/paste		

Salt, added to food or drink		
Sugar, white or brown, added to food or drink (e.g. on cereal, in drinks, etc.)		
Jam, marmalade		
Peanut butter		
Honey		
Chocolate spread (e.g. Nutella, etc.)		
Syrup (e.g. golden, maple, etc.)		
Yeast spreads (e.g. Marmite, Vegemite, etc.)		
Dips (e.g. cheese and onion dip, chunky basil pesto dip, etc.)		
Pate		
Other		

12. SWEET SNACKS	YES	NO
Chewing gum		
Chocolates		
Lollies		
Cakes (e.g. fruit loaf, muffins, carrot cake, etc.)		
Sweet bakery items (e.g. slices, pastries, tartlets, doughnuts, etc.)		
Plain biscuits (e.g. Superwines biscuits, Milk Arrowroot biscuits, etc.)		
Fancy biscuits (e.g. Tim Tams, Toffee pops, Squiggles, etc.)		
Pancakes, crepes, pikelets, waffles		
Desserts and puddings (e.g. bread and butter pudding, cheesecake, etc.)		
Jelly		
Ice blocks		
Other		

13. SAVOURY SNACKS	YES	NO
Chips/crisps		
Orange cheese puffs (e.g. Twisties, Cheezels, Rashuns, etc.)		
Corn chips (e.g. Dorito's, etc.)		
Savoury bakery items (e.g. quiche, etc.)		
Pretzels		

Popcorn		
Prepackaged bars (e.g. Muesli, Nut, Cereal bars, etc.)		
Bhuja mix		
Other		

14. TAKEAWAYS AND FASTFOOD	YES	NO
Pizza (e.g. Domino's, Hell's, etc.)		
Hamburger (e.g. Burger King, Burger Fuel, McDonalds, Fish & Chips Shop, etc.)		
Hot chips, French fries, kumara chips, potato wedges		
Battered hot dog		
Battered fish		
Fried chicken (e.g. KFC, etc.)		
Pies, sausage roll		
Chinese		
Indian		
Thai		
Sandwiches, wraps, pitas (e.g. Subway, Pita Pit, Turkish kebabs, etc.)		
Sushi		
Noodle canteen		
Other		

Massey University

Subject ID 250

The EXPLORE Study

Weighed 4 Day Food Record

Thank you very much for taking part in the EXPLORE Study.
We are extremely grateful for your time, effort and commitment!

If you have any questions, please contact EXPLORE staff on:
414 0800 (extn 41189) email: explore@massey.ac.nz or
Zara Houston 021 029 31620 AJ Hepburn 027 404 5351

All information in this diary will be treated with the strictest confidence. No one outside the study will have access to this.

We will arrange the return of your food diary and accelerometer (and may be in contact with you regarding the food diary).

Subject ID 250

What to do?

- Record all that you eat and drink on the following dates:

_____

_____

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- If possible record food at the time of eating or just after – try to avoid doing it from memory at the end of the day.
- Include all meals, snacks, and drinks, even tap water.
- Include anything you have added to foods such as sauces, gravies, spreads, dressings, etc.
- Write down any information that might indicate **size or weight** of the food to identify the portion size eaten.
- Use a new line for each food and drink. You can use more than one line for a food or drink. See the examples given.
- Use as many pages of the booklet as you need.

Describing Food and Drink

- Provide as much detail as possible about the type of food eaten. For example **brand names and varieties / types** of food.

General description	Food record description
Breakfast example – cereal, milk, sugar	1 cup Sanitarium Natural Muesli 1 cup Pam's whole milk 1 tsp Chelsea white sugar
Coffee	1 tsp Gregg's instant coffee 1 x 200ml cup of water 2 Tbsp Meadow fresh light green milk
Pasta	1 cup San Remo whole grain pasta spirals (boiled)
Pie	Big Ben Classic Mince and Cheese Pie (170g)

- Give details of all the **cooking methods** used. For example, fried, grilled, baked, poached, boiled…

General description	Food record description
2 eggs	2 size 7 eggs fried in 2tsp canola oil 2 size 6 eggs (soft boiled)
Fish	100g salmon (no skin) poached in 1 cup of water for 10 minutes

- When using foods that are cooked (eg. pasta, rice, meat, vegetables, etc), please record the **cooked portion** of food.

General description	Food record description
Rice	1 cup cooked Jasmine rice (cooked on stove top)
Meat	90g lean T-bone steak (fat and bone removed)
Vegetables	½ cup cooked mixed vegetables (Wattie's peas, corn, carrots)

- Please specify the **actual amount of food eaten** (eg. for leftovers, foods where there is waste)

General description	Food record description
Apple	1 x 120g Granny Smith Apple (peeled, core not eaten – core equated to ¼ of the apple)
Fried chicken drumstick	100g chicken drumstick (100g includes skin and bone); fried in 3 Tbsp Fern leaf semi-soft butter

- **Record recipes** of home prepared dishes where possible and the proportion of the dish you ate. There are blank pages for you to add recipes or additional information.

Recording the amounts of food you eat

It is important to also record the quantity of each food and drink consumed. This can be done in several ways.

- By using household measures – for example, cups, teaspoons and tablespoons. Eg. 1 cup frozen peas, 1 heaped teaspoon of sugar.

- By weight marked on the packages – eg. a 425g tin of baked beans, a 32g cereal bar, 600ml Coke

- Weighing the food – this is an ideal way to get an accurate idea of the quantity of food eaten, in particular for foods such as meat, fruits, vegetables and cheese.

- For bread – describe the size of the slices of bread (eg. sandwich, medium, toast) – also include brand and variety.

- Using comparisons – eg. Meat equal to the size of a pack of cards, a scoop of ice cream equal to the size of a hen's egg.

- Use the food record instructions provided to help describe portion sizes.

General description	Food record description
Cheese	1 heaped tablespoon of grated cheese 1 slice cheese (8.5 x 2.5 x 2mm) 1 cube cheese, match box size Grated cheese, size 10B

- If you go out for meals, describe the food eaten in as much detail as possible.

- ***Please eat as normally as possible - don't adjust what you would normally eat just because you are keeping a diet record! Your food record will be identified with a number rather than your name.***

Example day

Time food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed (units, measures, weight)
Example 7:55am	Sanitarium weetbix	2 weetbix
" "	Anchor Blue Top milk	150ml
" "	Chelsea white sugar	2 heaped teaspoons
" "	Orange juice (Citrus Tree with added calcium – nutrition label attached)	1 glass (275 ml)
10.00am	Raw Apple (gala)	Ate all of apple except the core, whole apple was 125g (core was ¼ of whole apple)
12.00pm	Home made pizza (recipe attached)	1 slice (similar size to 1 slice of sandwich bread, 2 Tbsp tomato paste, 4 olives, 2 rashers bacon (fat removed), 1 Tbsp chopped spring onion, 3 Tbsp mozzarella cheese)
1.00pm	Water	500ml plain tap water
3.00pm	Biscuits	6 x chocolate covered Girl Guide biscuits (standard size)
6.00pm	Lasagne	½ cup cooked mince, 1 cup cooked Budget lasagne shaped pasta , ½ cup Wattie's creamy mushroom and herb pasta sauce, ½ cup mixed vegetables (Pam's carrots, peas and corn), 4 Tbsp grated Edam cheese
6.30pm	Banana cake with chocolate icing (homemade, recipe attached)	1/8 of a cake (22cm diameter, 8 cm high), 2 Tbsp chocolate icing
" "	Tip Top Cookies and Cream ice cream	1 cup (250g)
7.30pm	Coffee	1 tsp Gregg's instant coffee 1 x 300ml cup of water 2 Tbsp Meadow fresh blue top milk 2 tsp sugar

Date_____ **DAY 1**

Time food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_____ **DAY 1 continued**

Time food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Recipes (Day 1)

Recipes (Day 2)

Date_____ **DAY 2**

Time food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_____ **DAY 2 continued**

Time food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_____ **DAY 3**

Time food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_____ **DAY 3 continued**

Time food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Recipes (Day 3)

Recipes (Day 4)

Date_____ **DAY 4**

Time food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

Date_____ **DAY 4 continued**

Time food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method)	Amount consumed

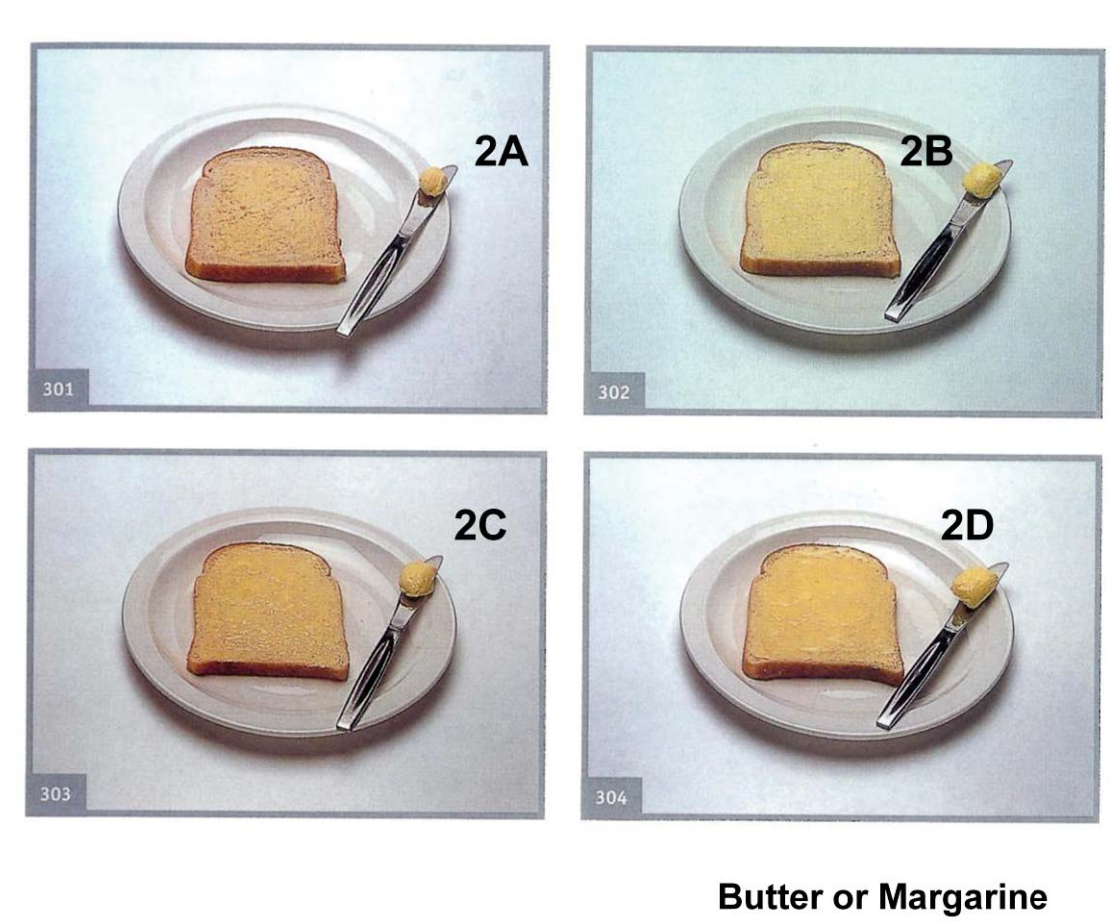
Massey University

Food Record Guide

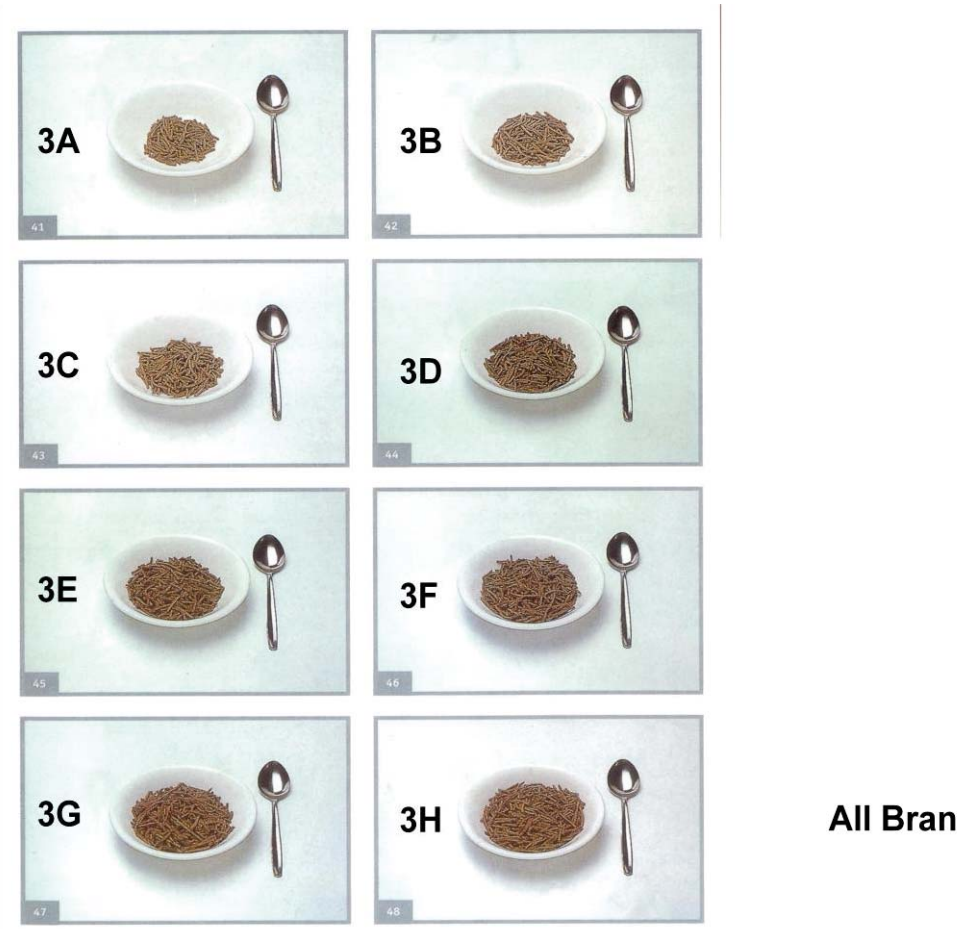
Institute of Food Nutrition and Human Health

Massey University

If you have any questions please contact EXPLORE staff on:
414 0800 (extn 41189) email: explore@massey.ac.nz or
AJ Hepburn 027 404 5351 Zara Houston 021 029 31620



Butter or Margarine


3A
41
3B
42
3C
43
3D
44
3E
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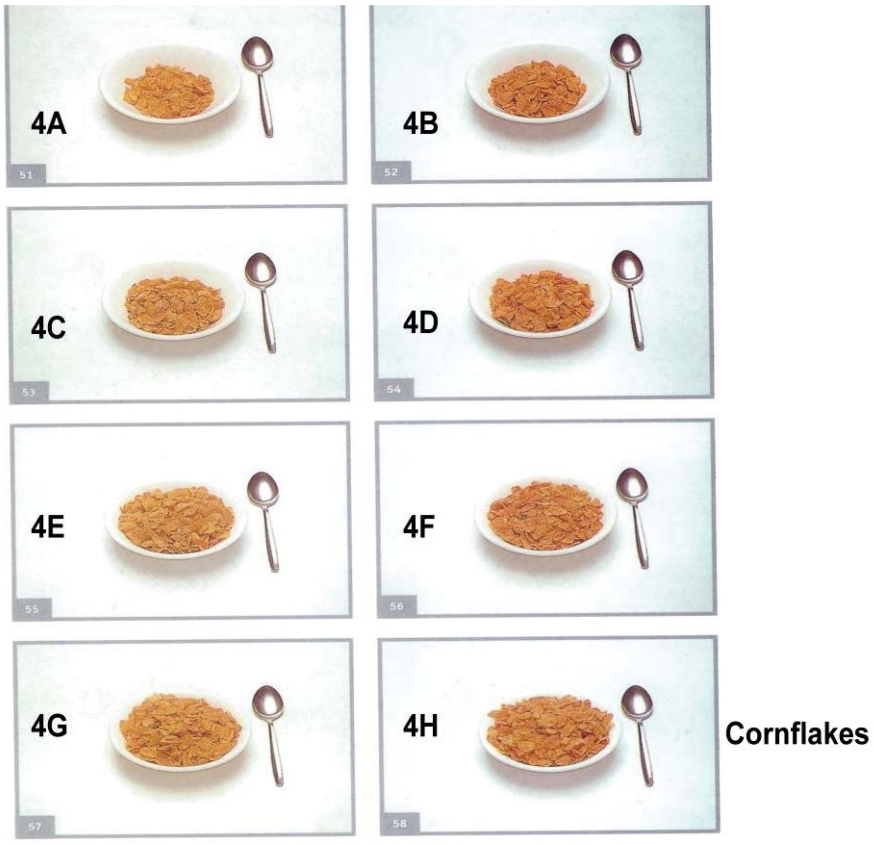
3F
46
3G
47
3H
48
All Bran


4A
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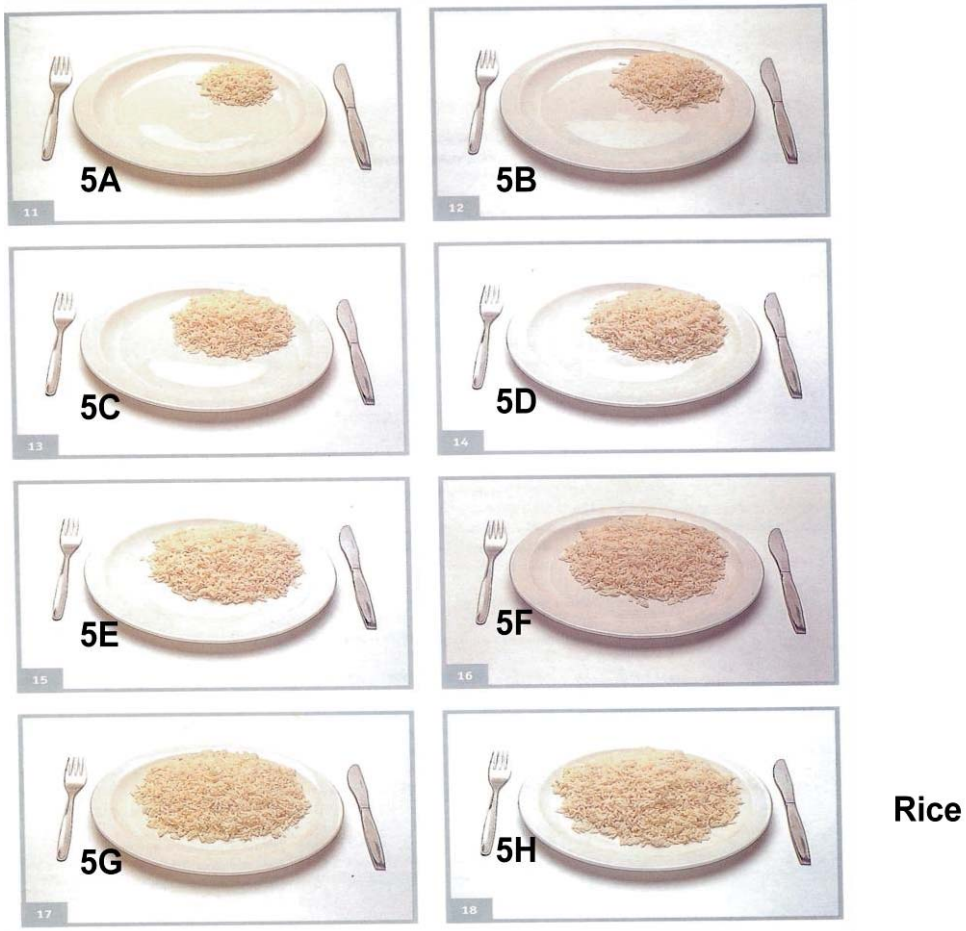
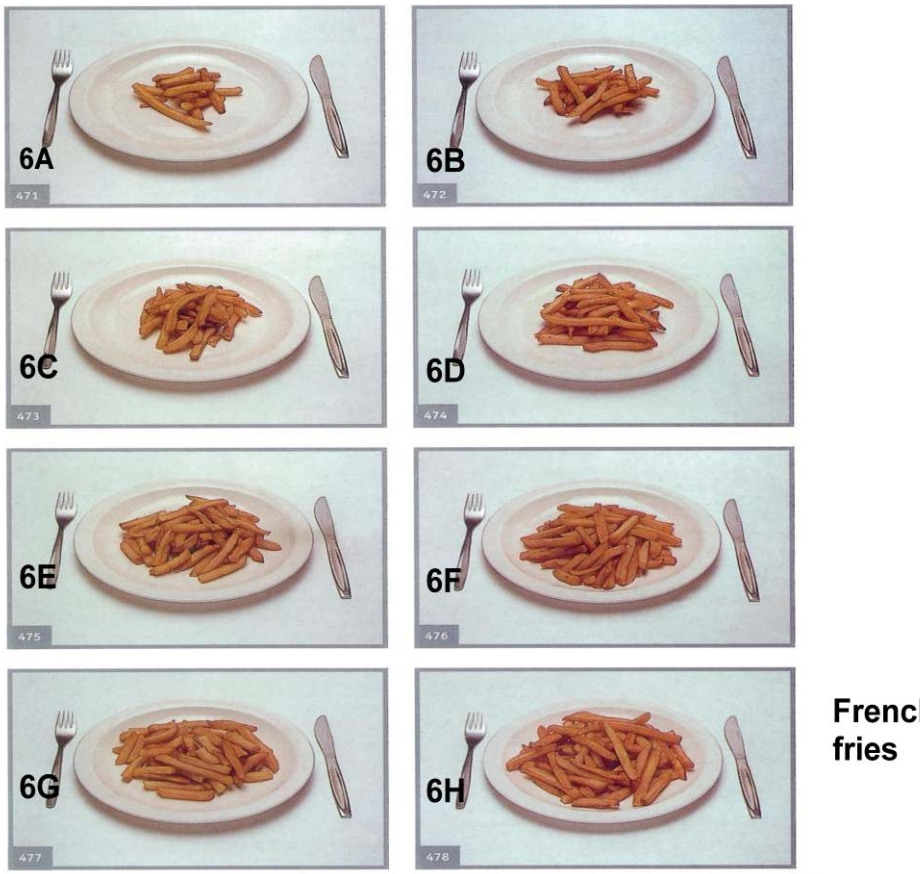
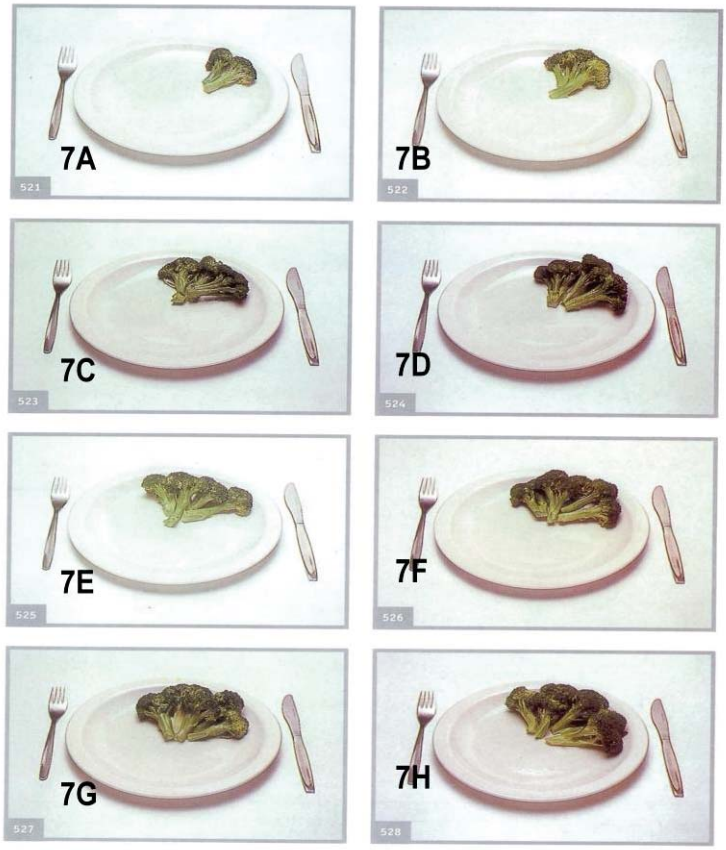
4H
58
Cornflakes



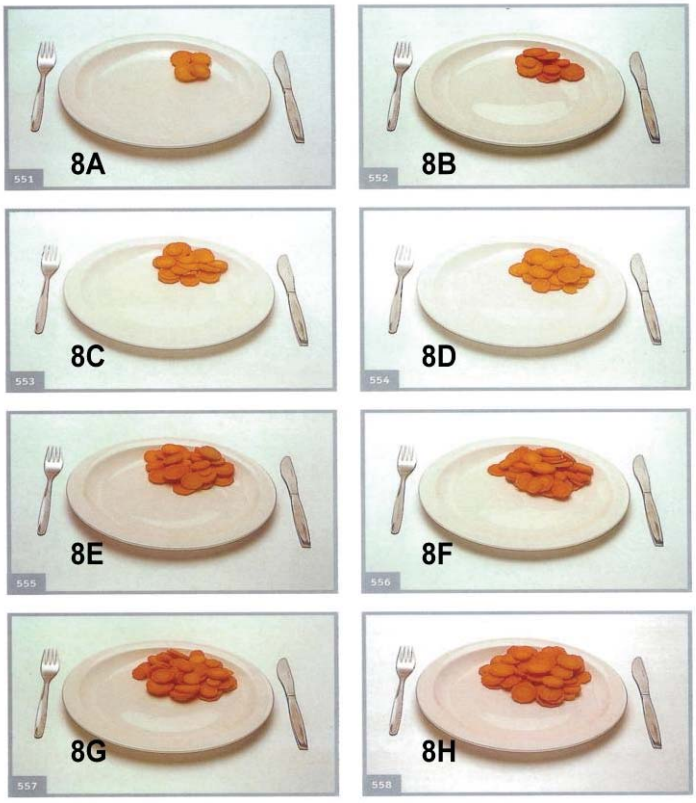
Rice



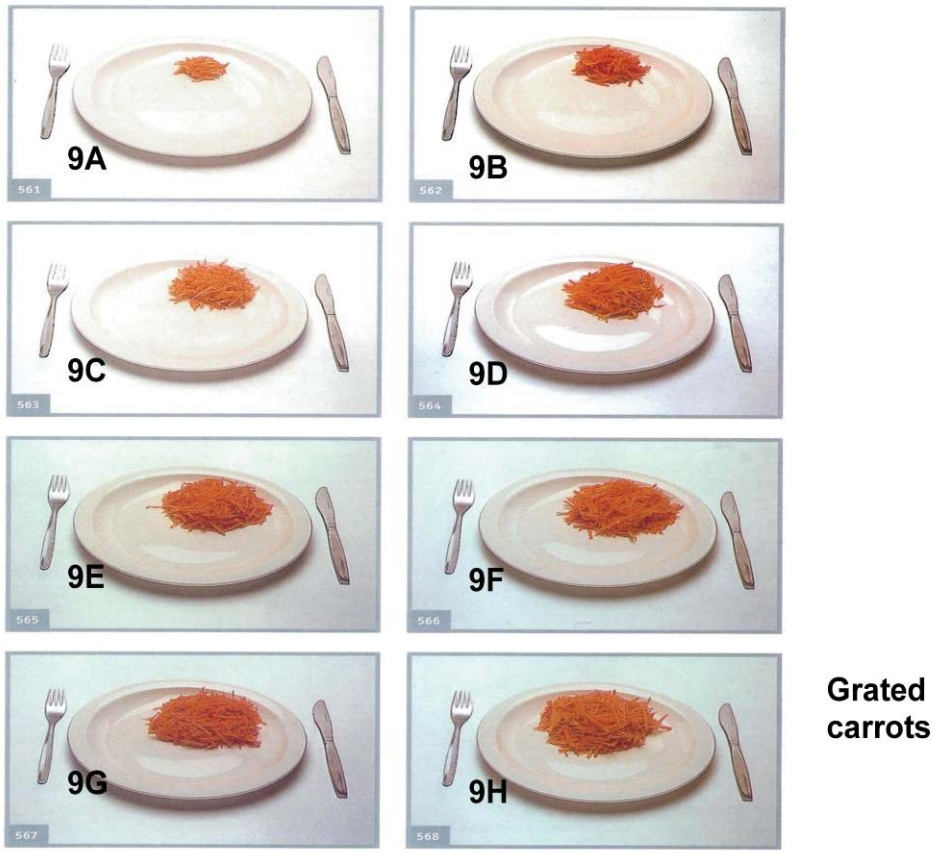
French fries



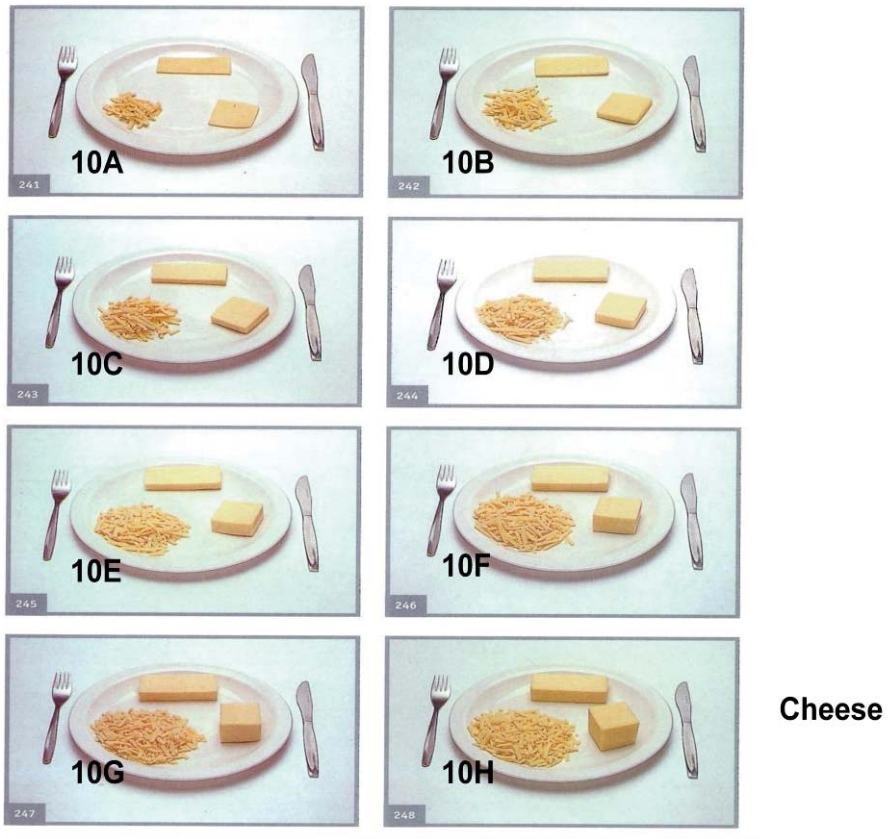
Broccoli



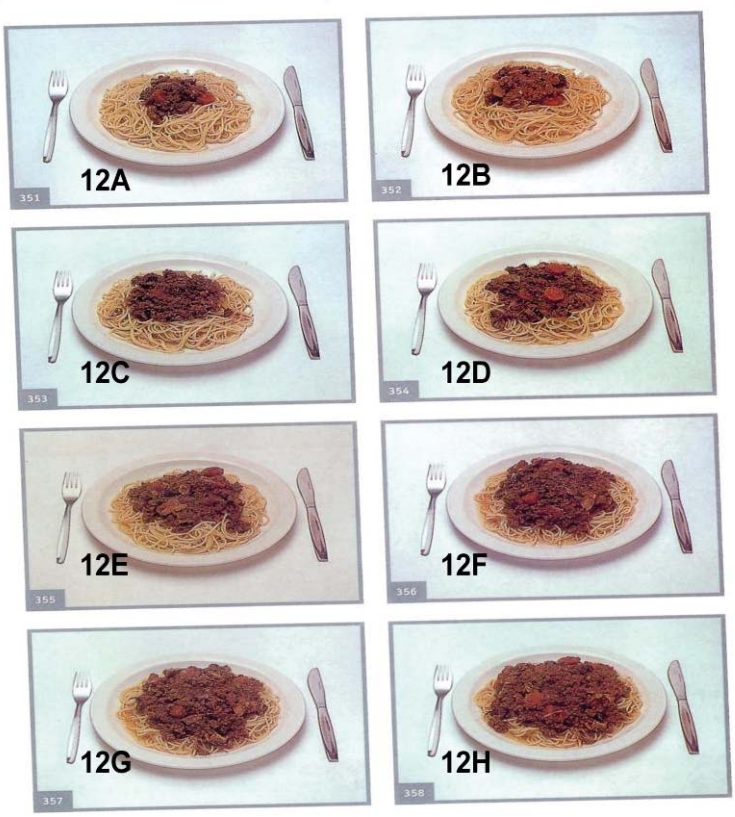
Sliced carrots



Grated carrots



Cheese


12A
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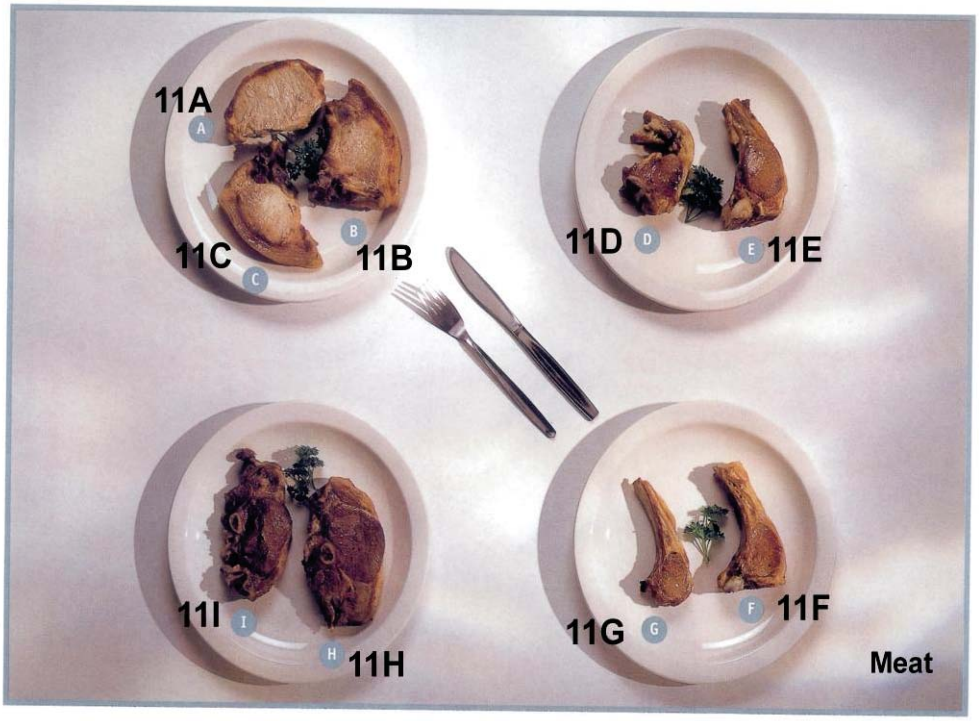
12G
12H
Pasta and Mince or Stew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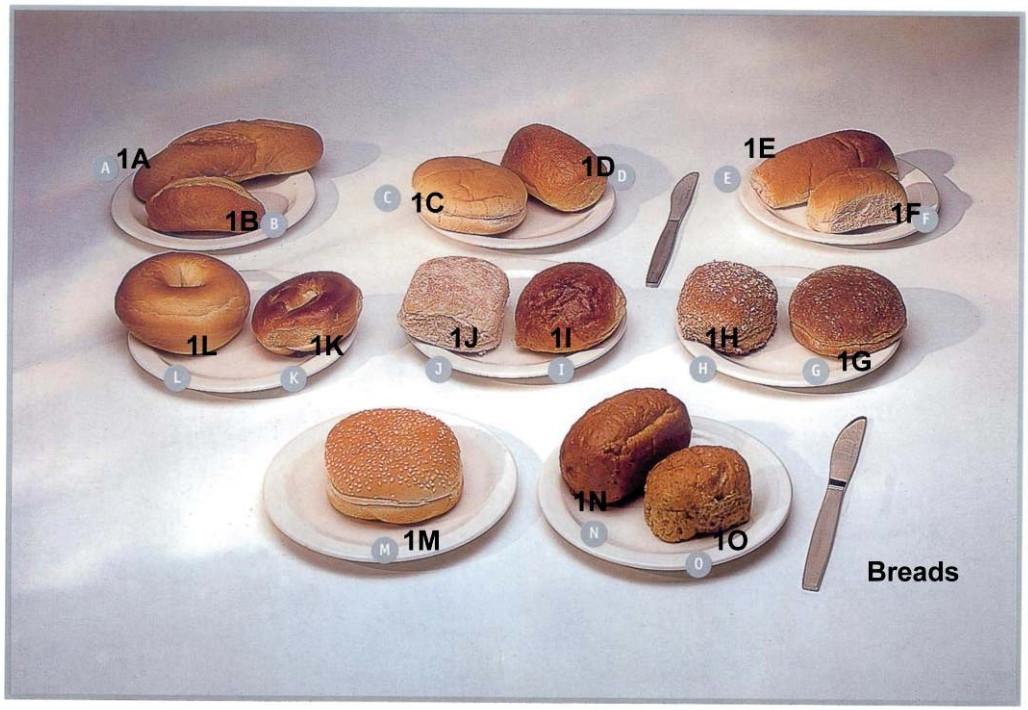
Meat


1A
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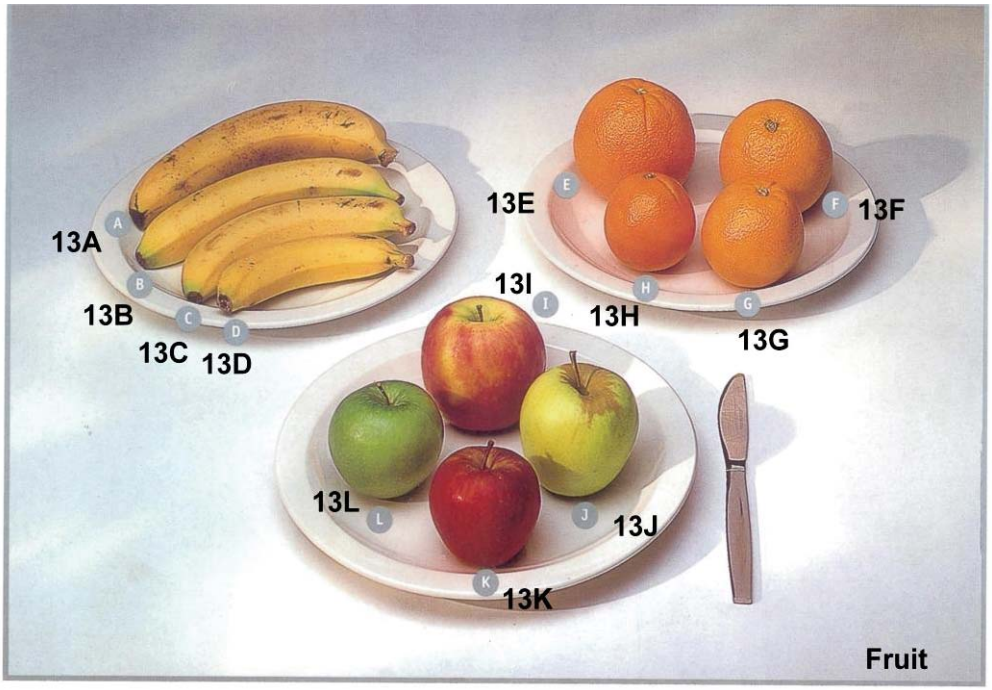
Breads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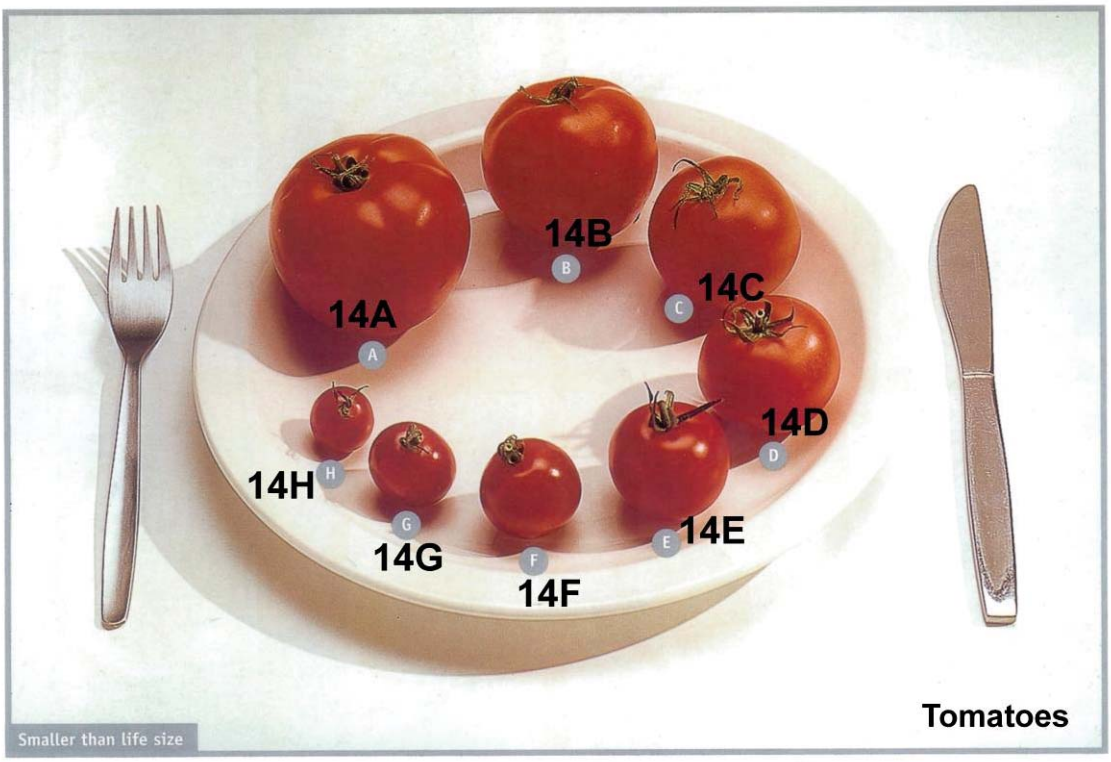
Fruit


14A
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14H
H
Smaller than life size
Tomatoes

Appendix D: SOP for DDQ

Women's EXPLORE (EXamining Predictors Linking Obesity Related Elements) Study

Summary of dietary diversity questionnaire SOP

Massey University

August 5, 2013

Complied by: Adrianna Hepburn

Approved by: Dr Rozanne Kruger, Dr Kathryn Beck

Table of Contents

A. Purpose and Applicability

The purpose of this SOP is to provide a guide for the study personnel involved in the EXPLORE study to follow when explaining to participants how they need to complete the dietary diversity questionnaire. This SOP will also include how participant can access the questionnaire, how to answer any participant questions, how to code for each person, and how the questionnaire can be returned. This questionnaire is being validated against a food diary so that it can be used again in future.

B. Summary of Method

The dietary diversity questionnaire will be given to subjects along with the accelerometer when they visit Massey University. They will be asked to complete the questionnaire either online or on paper at the end of the seven day period of wearing the accelerometer. If completed on paper, it needs to be sent back to the lab in the mail with the accelerometer.

C. Definitions

Dietary diversity = the variety of diet, measured by the amount of food types and food groups eaten

Accelerometer = a small device used to measure activity levels

Survey Monkey = a website that enables users to design their own online questionnaires and surveys

D. Cautions, Health and Safety Warnings

The questionnaires need to be checked over properly to ensure the questionnaire has been filled out correctly and that all boxes are ticked. If not, this could affect accuracy of results.

E. Interferences

If the participant does not understand how to fill out the questionnaire, this could affect the accuracy of the results. Instructions for the dietary questionnaire needs to be explained in adequate detail and opportunity for any questions by the participants should be provided.

F. Responsibilities

Whoever is on the questionnaire station needs to supply each participant with the questionnaire and instructions on how to fill it out and return it.

G. Equipment and Supplies

Printed versions of the questionnaire will need to be provided to each participant, as well as envelopes to return the questionnaires. Participants will also need to be provided with instructions to the web link for the online version of the questionnaire on Survey Monkey.

Have spare printed questionnaires available for participants to look through while they eat their breakfast.

H. Procedure

1. When participants reach the questionnaire station, they will be provided with a pack that contains the dietary diversity questionnaire, an envelope, and instructions on how to find the questionnaire online.

2. A copy of the questionnaire will be on hand to show each participant the format and to briefly explain how it should be answered.

Script:

Here is the dietary diversity questionnaire that you will need to fill out. This needs to be done at the end of the seven day period you wear your accelerometer. You will get a phone call reminding you to fill out the questionnaire.

The purpose of the dietary diversity questionnaire is for us to see how varied your diet is, for example how many different types of food you eat and from how many food groups you eat. It is important you fill out the questionnaire as honestly and accurately as possible.

When completing the questionnaire, you need to tick the "yes" column for foods you ate or drank only in the previous seven days, while you were wearing the accelerometer. You only need to tick a food once, even if it was consumed several times. If a food was not consumed in the last seven days, tick the "no" column for that food. Consider all preparation and cooking methods, as well as different packaging of food, for example if it is fresh, frozen, dried or tinned.

You can either fill out this questionnaire online, <u>or</u> you can fill in the paper version, it is up to you. If you would like to fill it in online there are instructions on how to find the questionnaire online in this pack. If you would like to fill it in on paper there is a copy inside this pack, as well

as an envelope so that you can return it to us in the mail when it is completed. Ensure your study ID is written on the questionnaire.

While you eat breakfast feel free to look through a copy of the dietary diversity questionnaire. If you have any questions please do ask.

3. When participants fill out the questionnaire online, they need to enter their participant ID number. Participants must put their ID on their questionnaire prior to returning it to the lab when filled out on paper.

4. Possible participant questions and answers:

- How long will this take me?

It will take approximately 10 minutes to complete.

- Do you not want to know how much of the foods I eat?

No, for the dietary diversity questionnaire it does not matter how much of a food you eat, you just need to indicate whether you have eaten a food or not. We are just interested in the types of food and what food groups you eat from.

- If a food is not included in the questionnaire what do I do?

At the end of each food group section there is an "other" option. Feel free to write any foods here that have not been included in the questionnaire.

- If I ate grapes (for example) last week, but not within the last seven days do I include it in the questionnaire?

No, only tick yes for the foods you have eaten in the last seven days.

- When do I send back the filled out questionnaire?

Soon as possible would be preferable. Send it back when you send you accelerometer back to us.

- If I would prefer to do the online option, when do I do the questionnaire?

You would still complete the questionnaire at the end of the seven day period you have been wearing the accelerometer.

- Where can I find my student code number for when I complete the DDQ online?

This can be found on your food record and will be in the reminder email we send you.

- If I have any questions while I am filling out the questionnaire is there someone who will be able to help me?

Yes, feel free to ring this number…if you have any questions, or email this email address…

- What do I do if my computer crashes during the middle of the questionnaire?

When your computer restarts, go back into the questionnaire. You may need to start the questionnaire again. Alternatively, you can complete the paper questionnaire version.

5. Ring participants at the end of their seven day period to remind them to fill out the questionnaire (and return it in the provided envelope if the paper copy is used).
6. Read and check over each individual questionnaire to check it has been filled out properly and that all boxes have been ticked.

I. Data and Records Management

Returned questionnaires will be collected and stored in a designated folder in building 27.
A list of study participant ID numbers should be kept, and when a questionnaire is returned or filled out online it can be ticked off the list.

J. Quality Control and Quality Assurance

Each of the returned questionnaires will be examined when they return back to Massey University to ensure they have been filled out properly, and to make sure all foods have been ticked. The data downloaded from Survey Monkey will be checked over to ensure all questions were answered, that each questionnaire was completed and that al questionnaires had a participant ID number.

Participants will receive a phone call at the end of the seven day period to remind them to do the questionnaire (and return it in the provided envelope if the paper copy is used).

To check instructions for the dietary diversity questionnaire are being given accurately, instructions should be explained to someone (outside of the EXPLORE study) as a practice, and then get the person to explain back what they need to do. This will show whether the instructions are understandable. If they do not understand, the person explaining the dietary diversity questionnaire needs to go back over the SOP to refresh their memory on what they need to explain to participants.

Appendix E: SOP for food record

Women's EXPLORE (EXamining Predictors Linking Obesity Related Elements) Study

Summary of food record SOP

Massey University

August 5, 2013

Complied by: Adrianna Hepburn

Approved by: Dr Rozanne Kruger, Dr Kathryn Beck

How to inform each participant of weighed four-day food record completion:

- Show participants the four-day food and food photo portion guide booklets, and give them a brief run down on its purpose and how to fill it out.

- Set participant up at computer to watch the DVD which explains how to keep a food record.

- On completion of watching the DVD, check whether the participant has any questions regarding the completion of the food diary.

- Emphasize the importance of being as honest and accurate as possible when filling out the food record, as it will allow a more accurate assessment of their current diet.

- Assign participants dates that they need to complete the food diary – the four consecutive days following testing, including at least one weekend day.

- Ask participants to return the food record as soon as they have completed the last day of recording, via stamped addressed envelope. Participants will also be sent a email to remind them to complete and return the food record during the week after they have come in for testing.

- Provide participant with electronic scales to weigh food if needed and a courier-stickered box to return the scales in.

Script:

*We have a short video for you to watch about how to keep a weighed food record for four days. Once you have watched it I can answer any questions or queries you've got.*Watch video**

*Here is the form for the weighed four-day food record. There is plenty of space to record all the food you eat for four days as well as any recipes you use. We also have this food guide (*give food photo guide*) for you to use if necessary, for example if you go out for a meal at a restaurant and are unable to weigh your food. We also have a set of electronic scales that you can borrow if you do not own your own. Would you like us to issue you some scales?*

The purpose of the weighed four-day food record is to allow us analyse the nutrient content of your current diet. It is important that you fill it out as accurately and honestly as possible. You need to record all the food and drink that you consume on four consecutive days – 2-3

*weekdays and 1-2 weekend days. We will ask you to do the food record the four consecutive days starting from tomorrow (*write dates in diary). Do you think that you will be able to do that, on the days that we have filled in for you?*

*What questions do you have about the food record? *Answer questions**

We then need you to get it returned to us, as soon as possible, in the stamped addressed envelope provided along with the accelerometer. Our contact details are on the front of the food record so please contact us with any questions or concerns.

Appendix F: Food groups used in anaylsis of dietary diversity

Food Group	Food Item
Meat	Lamb or mutton (e.g. chops, leg, stewing meat, flaps, etc.)
	Beef (e.g. steak, mince, stewing meat, etc.)
	Pork (e.g. chops, fillet, leg, etc.)
	Other meats (e.g. venison, etc.)
	Offal (liver, kidneys, heart etc.)
	Goat (meat)
Poultry	Chicken (e.g. whole, thighs, drumsticks, etc.)
	Chicken wings, nibbles
	Chicken offal (e.g. livers, hearts, giblets, chicken frames, etc.)
	Other poultry (e.g. turkey, duck, muttonbird, etc.)
Fish and seafood	Fish, fresh, white (e.g. hoki, snapper, flounder, etc.)
	Fish, fresh, brown or pink (e.g. salmon, trout, eel, etc.)
	Tinned tuna, salmon
	Other tinned fish (e.g. sardines, mackerel, herring, etc.)
	Roe (e.g. caviar, fish eggs, etc.)
	Shell fish (e.g. mussels, oysters, scallops, clams, pipis, cockles, paua, kina, etc.)
	Crayfish, shrimp, prawns, crab
	Squid, calamari, octopus
	Whitebait
Discretionary meat, fish and poultry	Hocks, pork bones, pig's head
	Crumbed, battered fish (e.g. fish fingers, fish cakes, etc.)
	Cured meat (e.g. ham, bacon, salami, etc.)
	Luncheon meats, all varieties
	Tinned meat (e.g. corned beef, etc.)
	Meat patties
	Sausage, all varieties
	Crumbed, battered chicken (e.g. chicken schnitzel, nuggets, etc.)
Eggs	Eggs
Nutritious dairy products	Full cream milk (dark blue top)
	Low-fat milk (light blue top)
	Skim milk (green top)
	Milk with calcium added (yellow top)
	Evaporated milk, tinned, (unsweetened)
	Fermented milk (Buttermilk, etc.)
	Yoghurt, full fat
	Yoghurt, low fat
	Other milks (e.g. soy milk, rice milk, almond milk, etc.)
Cheese	Hard cheese (e.g. edam, tasty, etc.)
	Soft cheese (e.g. cottage, ricotta, camembert, etc)
Discretionary dairy products	Sweetened condensed milk
	Cream or sour cream

	Processed cheese
	Custard
	Yoghurt drink
	Dairy food
Breads	Bread or rolls, whole-wheat, whole-grain, wheat-meal, multi-grain, etc.
	Bread or rolls, white
	Fruit bread or buns
	Specialty breads (e.g. croissant, panini, focaccia, pita, muffin splits, crumpets, etc.)
	Wraps
	Māori bread (rewena), doughboys
Cereals	Rice, all varieties (e.g. long grain, white, brown Basmati, Jasmine, etc.)
	Quinoa
	Porridge (e.g. rolled oats, oat meal, etc.)
	Bran flakes (e.g. All Bran, Special K Advantage, etc.)
	Wheat biscuits (e.g. Weet-Bix, etc.)
	Unsweetened breakfast cereals (e.g. Cornflakes, Rice Bubbles, etc.)
	Muesli, all varieties
	Liquid meal (e.g. Up and Go liquid breakfast, etc.)
	Couscous
	Pasta (e.g. macaroni, spaghetti, penne, etc.)
	Rice vermicelli (rice noodles)
	Scones
	Crackers (e.g. cream crackers, vita wheat, etc.)
Starchy vegetables	Potatoes
	Kumara (sweet potato)
	Taro
	Cassava
	Corn
	Green banana, plantain
	Swedes
	Turnip
	Parsnip
Discretionary breads, cereals and starchy vegetables	Instant noodles (two-minute noodles, all varieties, e.g. Maggi, Fantastic, etc.)
	Instant flavoured pasta packets (e.g. macaroni and cheese, chicken and mushroom, etc.)
	Dumpling (e.g. pork dumpling, red bean dumpling, etc.)
	Large savoury muffins (e.g. cheese, etc.)
	Sweetened breakfast cereals (e.g. Coco Pops, Fruit Loops, Nutri-Grain, etc.)
Legumes	Dried beans (e.g. kidney, sugar, red, butter, garbanzo, etc.)
	Canned beans (e.g. kidney, sugar, red, butter, garbanzo, etc.)
	Dried peas (green)
	Dried lentils (brown, red)
	Canned lentils (brown, red)

	Chick peas (e.g. in hummus, in falafels, etc)
	Tofu, tempeh
Nuts and seeds	Nuts (e.g. pecan, walnut, almond, cashew, etc.)
	Peanuts
	Seeds (e.g. sunflower, sesame, poppy, pumpkin, etc.)
	Coconut flesh
Vitamin A-rich fruit and vegetables	Peaches, yellow
	Apricots
	Mango
	Persimmon
	Tamarilo/tree tomato
	Prunes, dates
	Asparagus
	Broccoli
	Brussel sprouts
	Chinese greens (e.g. bok choy, pak choi, etc.)
	Capsicum, red
	Carrots
	Courgette/zucchini
	Mushroom
	Spring onions
	Pumpkin
	Puha
	Spinach, silverbeet, kale
	Squash (e.g. gem, butternut, etc.)
	Taro leaves
	Tomatoes
	Watercress
	Yams
Vitamin C-rich fruit and vegetables	Papaya/pawpaw
	Strawberry
	Kiwifruit
	Lemon, lime
	Orange
	Mandarin
	Feijoa
	Guava
	Gooseberry
	Melon, green or yellow
	Passion fruit
	Cauliflower
	Chili (red/green)
	Capsicum (green, yellow, orange, black)
Other fruits	Apple
	Peaches, white

	Pears
	Grapes
	Plum
	Banana
	Pineapple
	Avocado
	Berries (e.g. blueberry, boysenberry, etc.) and cherries
	Watermelon
	Lychees
	Raisins, sultanas, currants
Other vegetables	Onions
	Leeks
	Cabbage
	Red cabbage
	Rhubarb
	Beetroot
	Radishes
	Celery
	Cucumber
	Green beans
	Peas
	Lettuce, all varieties
	Eggplant/aubergine
	Garlic
	Artichoke
Oils and fats	Butter
	Clarified butter (e.g. ghee, etc.)
	Margarine, all varieties
	Margarine, all varieties, low fat or lite
	Lard (e.g. dripping, animal fat, etc.)
	Oil (e.g. olive, sunflower, canola, rice bran, etc.)
	Coconut cream (e.g. Kara, Fia Fia, etc.)
	Coconut milk (e.g. Kara, Ayam, Tropical, etc.)
Drinks	Juice (100% pure juice e.g. Ceres, Arano, etc.)
	Juice (<100% pure / imitation juice, e.g. Just Juice, McCoy, etc.)
	Imitation drinks (e.g. cordial, Raro, etc.)
	Soft drinks (e.g. Coke, Fanta, etc.)
	Diet soft drinks (e.g. Coke Zero, etc.)
	Flavoured milk (e.g. Milo, Nesquik, Primo, hot chocolate, milkshakes, Koko, etc.)
	Tea (e.g. Dilma, Twining's, etc.)
	Herbal tea (e.g. green tea, chamomile, etc.)
	Coffee, instant or brewed, with or without milk (e.g. flat white, espresso, etc.)
	Coffee-based drinks (e.g. latte, cappuccino, mochaccino etc.)

	Soups, instant, powdered (e.g. Cup a Soup, etc.)
	Energy drinks (e.g. Red Bull, Mother, etc.)
	Sports drinks (e.g. Powerade, Gatorade, etc.)
	Flavoured water (e.g. Mizone, h2go flavoured water, etc.)
	Water
Alcohol	Beer, all varieties, commercial
	Home brewed beer (e.g. hop beer, aaleve, etc.)
	Cider (e.g. Monteith's crushed apple, Magners, etc.)
	Wine (red or white)
	Spirits (e.g. rum, brandy, whiskey, etc.)
	Kava
	RTDs (ready-to-drinks) (e.g. Vodka Cruisers, Archers, etc.)
Sauces, spreads and flavourings	Tomato, BBQ, sweet chilli, mustard sauce, etc.
	Mayonnaise, salad cream or creamy dressings (e.g. aioli, tartare, etc.)
	Salad dressing (French, Italian, etc.)
	Chutney, relish
	White sauce, cheese sauce
	Gravy, homemade
	Gravy, packet (e.g. Maggi roast chicken gravy, Royal brown gravy, pepper sauce, etc.)
	Soy sauce
	Fish sauce/paste
	Salt, added to food or drink
	Sugar, white or brown, added to food or drink (e.g. on cereal, in drinks, etc.)
	Jam, marmalade
	Peanut butter
	Honey
	Chocolate spread (e.g. Nutella, etc.)
	Syrup (e.g. golden, maple, etc.)
	Yeast spreads (e.g. Marmite, Vegemite, etc.)
	Dips (e.g. cheese and onion dip, chunky basil pesto dip, etc.)
	Pate
Sweet snacks	Chewing gum
	Chocolates
	Lollies
	Cakes (e.g. fruit loaf, muffins, carrot cake, etc.)
	Sweet bakery items (e.g. slices, pastries, tartlets, doughnuts, etc.)
	Plain biscuits (e.g. Superwines biscuits, Milk Arrowroot biscuits, etc.)
	Fancy biscuits (e.g. Tim Tams, Toffee pops, Squiggles, etc.)
	Pancakes, crepes, pikelets, waffles
	Desserts and puddings (e.g. bread and butter pudding, cheesecake, etc.)
	Jelly
	Ice cream
	Ice blocks

Savoury snacks	Chips/crisps
	Orange cheese puffs (e.g. Twisties, Cheezels, Rashuns, etc.)
	Corn chips (e.g. Dorito's, etc.)
	Savoury bakery items (e.g. quiche, etc.)
	Pretzels
	Salted, flavoured nuts
	Popcorn
	Prepackaged bars (e.g. Muesli, Nut, Cereal bars, etc.)
	Bhuja mix
Takeaways and fast-food	Pizza (e.g. Domino's, Hell's, etc.)
	Hamburger (e.g. Burger King, Burger Fuel, McDonalds, Fish & Chips Shop, etc.)
	Hot chips, French fries, kumara chips, potato wedges
	Battered hot dog
	Battered fish
	Fried chicken (e.g. KFC, etc.)
	Pies, sausage roll
	Chinese
	Indian
	Thai
	Sandwiches, wraps, pitas (e.g. Subway, Pita Pit, Turkish kebabs, etc.)
	Sushi
	Noodle canteen

Appendix G: List of assumptions and decisions for calculation of dietary diversity measures using food records

Key: Food in food record = food selected in DDQ

Homemade pizza tomato base = tomato sauce

Naan = speciality bread

Silver top milk = full or cream

Marinade = sauce

Curry including paste = gravy sauce

Fresh and Fruity or no description of yoghurt = low fat variety

Cream cheese = soft cheese

Bagel = speciality bread

Smoked salmon = fresh salmon

Cookie = fancy biscuit

Scotch finger biscuit = plain

Anzac = plain biscuit

Peanut brownie = fancy biscuit

Homemade muesli = choose ingredients not muesli option

Green bean salad = green beans

Sesame dressing = creamy mayo

LSA or chia seeds = seeds

Chocolate sauce = chocolate

Peanut M&Ms = peanuts + chocolate

Bulgur = quinoa

Yoghurt raisins = raisins only

Subway = sandwich in take away option + meat + bread + lettuce + dressing

Homemade Juice = 100% juice + main ingredients

Granola = muesli

Pomegranate = berries

Kellogg's Just Right = unsweetened cereals

Satay stir fry = sauce + peanuts

Homemade apple crumble = oats apple sugar and butter

Frozen mixed vegetables= peas corn and carrots

Pumpkin soup in a pouch = pumpkin

Watties creamy pumpkin soup = pumpkin + soup option

Crispy noodle = crisps and chips

Peanut butter brownie= slice

Flat white = coffee based drink not instant or brewed!

Tangelo or grapefruit = orange

Tinned spaghetti = tomato sauce + pasta

Tortillas = wraps

Tomato pasta sauce= tomatoes and sauce

Coconut water = flavoured water

Pataks slow cooker mix and curry paste = gravy

Pizza bread = speciality bread

Chapattis = speciality bread

Bought apple pie= sweet bakery items

Spring rolls, samosas etc. = dumpling

Chicken Tonight (Creamy) = cream

Energy gels = sports drinks

Protein bars = packaged bars

Appendix H: Assumptions and decisions made during food record entry into FoodWorks

Food or topic	Assumptions and decisions	Reason
Days	- One day is 12am – 12am	- Technically this is the period of a day so follow to ensure consistency
When exact food item not on FoodWorks	- Food brand websites were used to find nutrient content of foods to determine which food to select on FoodWorks based on what foods had the closet nutrient composition	
Milk	- Select Auckland, November option - Silver top milk enter 4% total amount as cream, rest as trim milk - Oat milk entered as rice milk - Almond milk entered as soy milk	- Women live in Auckland and majority of women completing food records was done closer to November - Silver milk not an option, but is known to be 4% fat - Oat and almond not options, and oat milk similar nutrients to rice milk - Almond milk similar to soy milk.
Bread slices	- Select light if bread recorded by participant was like Pams or Molenberg brands - Select heavy if like Freya's or Ploughmans brands - If speciality bread e.g. soy and linseed, select soy and linseed or most similar type - Vogels and Burgen bread options available for selection - Upper North Island options selected where available.	- Options for bread broken down to light and heavy on FoodWorks so need to select most appropriate options and brands of bread eaten was a good way to do this - Participants in study live in Auckland.
Protein products	- Protein bar recipe created, made of skim milk powder, honey and milk chocolate; - Protein bar low carbohydrate recipe created, made of skim milk, honey and milk chocolate - Low carbohydrate protein powder recipe created, made of skim milk powder - Changed macronutrient values on all three recipes.	- To maintain consistency, a range of protein products available online were researched and three recipes were created to cover commonly consumed products by the women in the study - Recipes were based on common ingredients listed - Nutrient value of recipes were altered to match that on nutrient information panels (NIPs) of protein products - Changed macronutrient values in recipes to match those commonly eaten instead of entering new foods as creating new foods would mean many nutrient values would be missing (NIPs only have basic nutrient composition data)
McDonalds drinks	- Volumes: small 229ml; medium 328ml; large 501ml	- Based on sizes reported online

Aioli	- Select mayonnaise, commercial	- Most similar to aioli nutrient content
Gravy	- If made at home using powder, entered recipe where ratio not provided; recipe was 25g powder and 250ml water	- Based on recipe on gravy packet
Peanut butter	- Peanut butter with salt and sugar added unless stated otherwise	- Considered people who ate peanut butter with no salt or sugar added would be more conscious and hence record this in their food diary
Oil	- Composite if not specified	- Most generic option available
Size of spoons	- Tablespoon 15g; dessert spoon 10g; teaspoon 5g; heaped spoons add 0.25	- Based on common New Zealand guides (Bluebirds Foods Ltd, 1992)
Coffee	- For cafe-style coffees where information was lacking: Small is 200ml total volume, 30ml of this is espresso, the rest of volume is four parts milk and one part water; medium is 300ml total volume, 60ml of this is espresso, the rest of volume is four parts milk and one part water; large is 400ml total volume, 90ml espresso, the rest of volume four parts milk and one part water.	- Based on common sizes at cafes and where other participants recorded in great detail their coffees
Salt	- Pinch salt/pepper as 1.25g - Table salt unless specified otherwise	
Meat	- Meat entered as 70% of weight of raw meat	- Weight of meat is reduced after cooking processes; yield post cooking is on average around 70% (U.S. Department of Agriculture - Agricultural Research Service, 2012)
Canned meat	- Small tin take 20g off weight, large tin take 40g off weight when participant wrote they drained the fish/chicken	- Average amount of water or oil in tin that is drained off before eating
Sushi	- Enter 1 piece of sushi as rice,sushi,cooked,part of California rolls 45g, and 5g attributed to filling	- One piece of sushi estimated weight of 50g and the filling about 5g.
Margarine	- Polyunsaturated margarine included those brands like Meadowlea, Sunrise, Flora - Monounsaturated margarine included Olivio and Olivani - Dairy blends included Anchor spreadable	- Margarine entered based on brands provided in food diaries