Determining the Relative Validity and Reproducibility of a Food Frequency Questionnaire (FFQ) to Assess Nutrient Intake in Older Adults living in New Zealand

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Science

In

Nutrition and Dietetics

At Massey University, Albany

New Zealand

Angela Dawn Yu

2019

Abstract

Background: New Zealand's population is ageing. Dietary intakes in older adults and physiological changes through ageing are important predictors of health and disease outcomes. However, it is challenging to capture the typical diet of older adults. Among different types of dietary assessment tools, a food frequency questionnaire (FFQ) is easy to administer and causes less burden to participants. To the best of our knowledge, the latest FFQ validation study in older adults was undertaken nearly 30 years ago. A valid and reproducible FFQ to measure multiple nutrients intake in older New Zealanders is warranted.

Aim: This study aims to assess the validity and reproducibility of an FFQ designed to measure a range of relative nutrient intakes in older adults aged 65 to 74 years in New Zealand.

Methods: As part of the Researching Eating, Activity and Cognitive Health (REACH) study, a convenience sample of community-dwelling older adults 65 to 74 years were recruited for a cross-sectional observational study. Participants (n = 166) who completed a 109-item FFQ to assess dietary intakes over the past month and a four-day food record (4DFR) were included in the validity analysis; participants (n = 319) who completed the FFQ and re-administered FFQ four weeks later were included in the reproducibility analysis. Energy intake was adjusted for nutrients in the statistical methods. Relative validity and reproducibility of the FFQ were assessed using paired t-tests, Pearson' or Spearman's correlation coefficients, cross-classification with weighted kappa statistics, Bland-Altman plots, and linear regression analysis for energy and 28 nutrients.

Results: Energy adjustment caused moderate improvements on both validity and reproducibility. The validity correlations for energy adjusted nutrient intakes ranged from 0.05 (selenium) to 0.76 (alcohol), with a mean of 0.35. Validity correlations above 0.40 were observed for 12 nutrients after energy adjustment, including carbohydrate, sugar, dietary fibre, total fat, monounsaturated fat, polyunsaturated fat, cholesterol, vitamin E, calcium, and magnesium. At least 50% of participants were correctly classified into the same tertiles for nine nutrients. Less than 10% of participants were grossly misclassified into the opposite tertiles for seven nutrients. Weighted kappa values for validity demonstrated fair agreement (κ 0.21-0.40) for 19 nutrients and good agreement (κ >0.61) for alcohol intake. Reproducibility correlations for energy adjusted nutrients ranged from 0.30 (vitamin A) to

0.91 (alcohol), with most nutrients (n = 25) falling between 0.60 and 0.80. For reproducibility, the mean correct classification was 60%, ranged between 53 and 78%. Gross misclassification for energy adjusted nutrients ranged from 0.6 to 7.8%. Weighted kappa values for reproducibility demonstrated moderate agreements (κ 0.41-0.60) for 25 energy adjusted nutrients and good agreement (κ >0.61) for alcohol.

Conclusion: The FFQ showed reasonable relative validity for ranking nutrient intakes in older New Zealanders 65-74 years old. The FFQ appears to have good reproducibility for assessing energy and nutrient intakes. The FFQ could be used in future research for relative nutrient assessments in older adults but is not suitable for measuring absolute nutrient intakes.

Keywords: ageing; elderly; reliability; validation; food diary; dietary questionnaire; macronutrient; micronutrient

Acknowledgements

I would like to acknowledge a number of people who were involved in this study. Firstly, I would like to thank my parents who provided endless support throughout my study.

I would like to thank Dr Kathryn Beck and Dr Cathryn Conlon, my two academic supervisors who kindly guided me with their wisdom and professional knowledge; encouraged me in every meeting, dedicated their time to the study and helped me with editing, statistical analysis, and any obstacles I encountered.

I would like to give special thanks Karen Mumme who helped me with data management; one of the most crucial process to have a reliable dataset for the nutrient intakes, and making an extra effort assisting me with her exceptional knowledge in software.

I would also like to thank Dr Pam von Hurst, Owen Mugridge, Cassie Slade, Nicola Gillies, Harriet Guy, and Cherise Pendergrast. I am grateful for their remarkable contribution to the REACH study; without their assistance in recruitment, data collection and entry, this study would not have succeeded.

Table of Contents

List of Tables

List of Figures

Chapter Three: Research Manuscript

Chapter Five: Appendices

Abbreviation List

4DFR	Four-day Food Record
BMI	Body Mass Index
BMR	Basal Metabolic Rate
CI	Confidence Intervals
EI	Energy Intake
FFQ	Food Frequency Questionnaire
FFQ1	First Food Frequency Questionnaire
FFQ2	Second Food Frequency Questionnaire
FR	Food Record
LOA	Limits of Agreement
MoH	Ministry of Health
MU	Massey University
MUFA	Monounsaturated Fatty Acid
NDNS	National Diet and Nutrition Survey
NZ	New Zealand
PUFA	Polyunsaturated Fatty Acid
REACH	Researching Eating, Activity and Cognitive Health
RDA	Recommended Daily Allowance
RDI	Recommended Dietary Intake
SAFA	Saturated Fatty Acid
SD	Standard deviation
UK	United Kingdom
WHO	World Health Organisation
n	number
κ	Kappa statistics
r	Correlation coefficients
y	year
<	Less than
>	Greater than
≤	Equal to or less than
≥	Equal to or greater than

Chapter One: Introduction

1.1 Background

New Zealand is experiencing population ageing. According to the Ministry of Health (MoH), people aged 65 years and over are expected to make up 26% of the New Zealand population by 2051 (Ministry of Health, 2002). Physical and physiological changes due to ageing can increase the risk of malnutrition, unintended weight loss, and decrease muscle mass (Hickson, 2006). A combination of ageing and poor dietary intake can result in higher risks of chronic metabolic diseases (Chernoff, 2001; Li and Heber, 2012). In New Zealand, older adults aged 65 to 74 years carry a heavier burden of chronic diseases such as coronary heart disease, bowel cancer, musculoskeletal disorders, with vascular disease being the main cause of health loss (Ministry of Health, 2016). Therefore, dietary intakes become a major predictor of health and the quality of life in older adults (Milte and McNaughton, 2016).

A widespread insufficient intake of micronutrients has been observed in adults over 65 years old. These include nutrients such as thiamine, riboflavin, calcium, magnesium, and selenium (Hoffman, 2017). Furthermore, measures of suboptimal calcium and vitamin D intake in older adults contribute to the development of osteoporosis (Lips, 2001; Hughes *et al*., 1997); whereas adequate dietary protein is associated with a lower prevalence of sarcopenia in later-life (Yang *et al*., 2019). Suboptimal intake is a concern in the ageing population and may contribute to increased health costs in New Zealand (Cornwall and Davey; 2004, Stefanogiannis *et al*., 2005).

Currently, dietary intake and eating patterns in older adults require further investigation. As dietary intake is closely associated with older adult's health and their wellbeing (Rush and Yan, 2017), it is imperative to have robust and accurate tools available to assess dietary intake. Otherwise, false associations can occur between dietary intakes and health outcomes if the dietary assessment tool used is not valid and/or reliable. However, dietary assessment is challenging and presents greater challenges in older adults, for example, due to changes in cognition, poor vision, chronic illness, or use of supplements. (Drewnowski and Evans, 2001; Thompson and Subar, 2017).

Typically, a weighed or estimated food record (where participants record all foods and beverages eaten over a specific period) is used to assess dietary intake. However, the

completion of a food record is time-consuming, expensive, and requires intensive labour. On the other hand, a food frequency questionnaire (FFQ) is an alternative dietary assessment method where participants select how often they consume foods and beverages from a list provided. Compared with a food record, an FFQ is relatively more cost-effective, time-efficient, and presents less burden for both the participants and researchers (Willett *et al.*, 1985, Willett, 2012). An FFQ should be current and contain foods consumed by the population it is intended to be used in. Furthermore, an FFQ should be validated in the population of interest to ensure the FFQ is measuring what it intends to measure (Beck *et al.*, 2018, Cade *et al*., 2002). The reliability or reproducibility of a dietary assessment tool is also important. A well-established "reproducibility" ensures that when the FFQ is re-administered in the same population at a different point of time, the collected dietary information has minimum disparities between the two results (Cade *et al.*, 2002, Miller *et al.*, 2010).

While FFQs used in adults have been validated in New Zealand (Ingram *et al.*, 2012; Beck *et al.*, 2012; Sam *et al*., 2014; Wilson and Horwath, 1996), an FFQ to measure multiple nutrient intakes specifically in older adults aged 65 to 74 years has not been developed or validated. In New Zealand, to the best of our knowledge, the only validated FFQ aimed at older adults was designed nearly 30 years ago and focused on calcium intake in a small population (53 older participants) living in Dunedin (Horwath, 1993). Therefore, the development and validation of an FFQ which assesses a wide range of nutrients in older adults is warranted.

1.2 Purpose of the Study

The purpose of this study was to assess the relative validity and reproducibility of a semi-quantitative FFQ designed to measure the relative intake of multiple nutrients in older adults age 65 to 74, living in New Zealand. If valid and reproducible, the FFQ could be used in future studies in older New Zealanders to assess a range of nutrient intakes.

1.3 Aim

The aim of this study was to evaluate the relative validity and reproducibility of a semi-quantitative FFQ for assessing nutrient intakes in older adults aged 65 to 74 years living in New Zealand.

1.4 Objectives

- To validate a semi-quantitative food frequency questionnaire against a four-day food record for nutrient intakes in older adults.
- To evaluate the reproducibility of a food frequency questionnaire (using two FFQ's administered four weeks apart) for nutrient intakes in older adults.

1.5 Hypothesis

The semi-quantitative FFQ is a relatively valid and reliable dietary assessment tool for assessing relative nutrient intake in an older population living in New Zealand.

1.6 Thesis Structure

The first chapter introduces the study background and outlines the aim and objectives of this research. The second chapter is a narrative literature review, which addresses dietary intakes in older adults, nutritional associated health risks, the rationale for using a valid and reproducible FFQ for assessing nutrient intake, and the reviews of current validated FFQs available for use in older adults. The third chapter is the research manuscript, which presents the methodology and the results of the study, as well as a discussion of the findings observed. The fourth chapter is the conclusion, which includes strengths and limitations, recommendations for future research, and a conclusion.

1.7 Researchers' Contributions

Table 1.1 Contribution of researchers to the study

Researcher	Contributions to thesis
Angela Yu	Main researcher and author, assistance with data collection. Data entry of the 4DFR. Statistical analysis, writing, editing, and final preparation of the thesis.
Associate Professor Kathryn Beck	Primary supervisor of the FFQ validation study. Principal investigator of the REACH study. Application for research ethics, development of the FFQ, assistance with data collection, statistical analysis and interpretation of the data.
Associate Professor Cathryn Conlon	Co-supervisor of the FFQ validation study. Co-investigator of the REACH study. Assistance with data collection, development of the FFQ and interpretation of data.
Nicola Gillies, Cherise Pendergrast, and Harriet Guy	Assistance with data collection and data entry of the 4DFR.
Karen Mumme	Assistance with data collection and 4DFR data entry, management and review of the FFQ data. Contributed to the development of the FFQ.
Owen Mugridge	Project co-ordinator of the REACH study. Participant recruitment and data collection.
Cassie Slade	Participant recruitment, data collection and assistance with entry of the 4DFR.

Abbreviations: FFQ, Food frequency questionnaire; 4DFR, Four-day food record; REACH, Researching Eating, Activity and Cognitive Health.

Chapter Two: Literature Review

2.1 Introduction

The literature review covers several aspects related to the assessment of dietary intake in older adults, including the associations between dietary intake and health outcomes in older populations, various dietary assessment methods, and limitations and challenges in assessing dietary intakes including those in older adults. The literature reviews validation studies of food frequencies questionnaires (FFQ) undertaken in older adults internationally and in adults living in New Zealand.

Relevant literature and references were searched from the following databases: Massey University Library Database, PubMed, Web of Science, Google Scholar, and the National Centre for Biotechnology Information. The publication year of the reviews ranged from 1961 to 2019. The searched keywords were food frequency questionnaire, nutrient intakes, older adults/elderly, validation, validity, reproducibility, reliability, repeatability, and New Zealand. Key terms were also used in combination with the two functions 'AND' 'OR'. Searched references were limited to English published journal articles.

2.2 Dietary intake and health in older adults in New Zealand

Older New Zealanders are exposed to a dynamic range of nutritional risk factors including both sedentary lifestyles and nutrient deficiencies. Poor diet and lifestyle may lead to detrimental effects on health, functionality, and the quality of life in older adults (Watson *et al*., 2018). In New Zealand, inadequate protein intake was identified for three quarters of an advanced aged group (80 years and above). Low intake of protein foods can contribute to adverse health outcomes (North *et al*., 2018). On the other hand, sufficient protein intake may decrease rates of hospitalisation due to reducing infections among older community-living adults (Wham et al, 2015). Furthermore, it has been suggested a diet providing twice the recommended daily allowance (RDA) or a 25% increase in the recommended dietary intake (RDI) of protein to be beneficial for the population over 70 years old to maintain muscle mass and leg strength (Scott *et al*., 2010; Mitchell *et al*., 2017). In community settings, there is a higher risk for deficiencies or inadequate intakes of macro-and micro-nutrients in older adults compared to younger groups including protein, vitamin D, thiamine, riboflavin,

calcium, magnesium, and selenium (ter Borg *et al*., 2015). For example, there are re-emerging deficiencies of iodine in older New Zealander in recent years. The median urinary iodine concentration (72 mcg/l) in older New Zealanders over 60 years living in residential care was below the standard (100-199 mcg/l) indicating mild iodine deficiency (Miller *et al*., 2016). Furthermore, the National Nutrition Survey 2008/09 reflected a high occurrence of inadequate intake of calcium and vitamin D in older adults (Otago University and Ministry of Health, 2011). These deficiencies can diminish one's optimal health, particularly in older adults; calcium is of major importance for attaining and maintaining bone health (Li *et al*., 2018), while inadequate dietary vitamin D intake and sun exposure are associated with increased risks of fractures, falls, and poor muscle strength in older adults (MacDonell *et al*., 2016). From reviewing the current literature, suboptimal macro-and micro-nutrient intake remains an issue in an ageing population in New Zealand.

Increased chronic disease risks may also have an impact on the health system due to population ageing. According to the Ministry of Health, health loss varies by gender and age groups, with cancer being the greatest disease burden in men and musculoskeletal disorders in women. In addition to this, the leading causes of health loss in older adults aged 65 to 74 years include cancers (mainly lung and bowel cancers), coronary heart disease, vascular disorders and musculoskeletal conditions. The report from the New Zealand Burden of Diseases study suggests that while the population will have a longer life expectancy, the population may also live a longer life in poor health (Ministry of Health, 2016).

By further investigating nutrient intakes in older adults and identifying nutritional risk factors, there could be an opportunity to reduce potential nutrition-related disease/chronic disease in the ageing population.

2.3 Dietary assessment methods

There are four main types of dietary assessment tools. These include the FFQ, food records, 24-hour recall, and diet history. The strengths and weaknesses of these four dietary assessment tools are outlined in Table 2.1 (Willett, 2012).

2.3.1 Food frequency questionnaire

The FFQ is a retrospective dietary assessment tool which asks participants how often they consume food items over a retrospective period of time, ranging from weeks to years. An

FFQ can be qualitative by assessing frequency only, or semi-quantitative which allows estimation of the food portion. The FFQ is generally recognised as an effective tool to estimate long term diets and nutrient intakes and has been widely used in large epidemiological studies since the 1990s (Shim *et al*., 2014).

Longer FFQs (at least 100 items) are useful for estimating habitual dietary and nutrient intake. An FFQ can be designed to fit specific study populations and research aims/hypothesis. For example, a shorter FFQ is a suitable method for estimating specific nutrient intakes such as calcium in older women (Willett, 2012). An FFQ is often used in studies with larger populations as it is cost-effective and less burdensome to the researchers compared to a 24-hour recall or food record. Because FFQs are easy for participants to complete; the overall respondent rate is relatively high, making the FFQ extremely practical in epidemiologic studies (Willett, 2012; McNeill *et al*., 2008).

However, there are limitations in using an FFQ. The FFQ may not be suitable for cross-country studies unless the cultural diets and food lists are analogous. Additionally, the FFQ depends on good memory for well-established food intake over a long period of time. It can be difficult for some participants to report accurate frequency and portion size of consumed foods by memory, particularly if cognitive function is impaired. For measuring absolute food and/or nutrient intake, a seven-day food record is considered more suitable than an FFQ due to how dietary intake is measured (Willett, 2001).

2.3.2 Food record

Food records, also known as food diaries, are prospective, short-term methods where details of all foods and drinks consumed are recorded by the participant, usually over several days (four to ten days) (Thompson *et al*., 2001). Self-administered food records do not depend on memory and allow quantitative measurements of the amounts of foods consumed (McNeill *et al*., 2008). Food records allow greater flexibility in terms of the consumed foods, as FFQs are usually restricted to a pre-determined list of food items; complex meal items and recipes documented in food records can provide more detailed nutrition information (Willett, 2012). Food records can either be estimated or weighed. Weighed food records require the use of kitchen scales to record food intakes. Estimated records rely on participants' subjective estimation using images, household measures, food models, or no particular aids (Thompson and Byers, 1994). A weighed food record is usually perceived as the most accurate dietary assessment tool, which in turn increases participants' burden, particularly with weighing food

intakes over seven days or more. Additionally, the process of documentation may promote participants' bias to selectively change their eating behaviours and may lead to less representative dietary intakes (Willett, 2012).

2.3.3 24-hour recall

The 24-hour recall is a retrospective assessment method usually administered by a trained interviewer. The main purpose of a 24-hour recall is to assess detailed dietary data covering dietary intake over the past day or 24 hours. The 24-hour recall allows additional information to be collected such as supplement use, meal preparation, and environmental factors such as where and when foods and beverages were consumed (Mertens *et al.*, 2019). While still dependent on memory, the 24-hour recall is subjectively less burdensome on memory than that of an FFQ (Willett, 2012; Cade *et al.*, 2002). However, the use of a 24-hour recall may not reflect the usual dietary intake, thus, a 24-hour recall is most useful in larger sample size or when multiple 24-hour recalls are undertaken in the population (Thompson *et al.*, 2001).

2.3.4 Diet history

A diet history is a subjective measure with closed-and open-ended questions typically administered by trained dietitians and nutritionists; and is often used in clinical settings. The diet history can assess both long and short term dietary intake. One of the key advantages is the ability to capture detailed information about habitual diet and food intake at a specific life stage or over a specific period. The diet history is suitable to assess meal patterns, food preparation, and portion sizes. However, the information gathered is heavily dependent on the researcher/interviewer's skill. Interview based methods can create bias and result in skewed data (Thompson *et al.*, 2001). The diet history is generally high cost and time-consuming, making this assessment method less suitable for epidemiological studies, especially with large sample sizes (Shim *et al.*, 2014).

In addition to these traditional dietary assessment methods, new methods are emerging that utilize technology and offer many advantages over traditional methods (and are often preferable to participants). These new technologies include online-dietary questionnaires and 24-hour recalls, digital images, mobile food records, and food record applications (Eldridge *et al.*, 2018). However, the use of new technologies has its challenges and technology changes rapidly. The use of digital images and applications can be time-consuming and may not always be practical for use in large epidemiologic studies in older adults (Amoutzopoulos *et al.*, 2018).

Table 2.1 Strengths and weaknesses of the four main dietary assessment methods

Dietary assessment methods	Strengths	Weakness
Food frequency questionnaire	• Assesses usual dietary intake. • Cost effective and less burdensome for interviewer/researcher and participants. • Can be designed or modified to measure certain nutrient or dietary patterns.	• Is memory-based. • Self-administered FFQ requires literacy and numeracy skills. • Estimating accurate portion sizes can be difficult. • FFQs are population specific, and may not be appropriate for different populations. • Restricted food items: Ready-to-eat meals and takeaways have complex nutrition information and may not be included in the food list.
Food records	• Provides detailed dietary information on all consumed food and drinks. • Relatively accurate estimations on dietary intake due to portion size description/ food weight. • Less reliance on memory if food is recorded at the time of consumption. • With standardised instructions and rules, misreporting can minimised. • Information provided can be followed up by trained researchers.	• High participant and researcher burden. • Potential for low respondent and low completion rate. • Requires good literacy and numeracy.
24-hr recalls	• Provides detailed dietary data over the past day 24 hours, multiple 24 hour recalls for long term intake. • Multiple 24 hour recalls can be used to assess long term dietary intake. • Able to assess meal pattern (meal time), location, and food preparation. • Individual literacy is not required.	• Single 24 hour recall is unable to account for variations across days. • Collected data depends on interviewer experience and skill. • Moderate to high burden to researchers. • Relatively expensive and time consuming for researchers.
Diet history	• Individual literacy is not required. • Able to assess habitual diet, meal pattern (meal time), and food preparation. • Food portions assessed by trained professionals are relatively accurate.	• Expensive and time consuming for researchers. • Collected data depends on the interviewer experience and skill.

2.4 Dietary assessment challenges including those in older adults population

Dietary assessment of older population can be complex and present several challenges for researchers when assessing dietary intakes in older adults. These challenges are reviewed below.

2.4.1 Under-reporting

Under-and over-reporting is a common issue with assessing dietary intake in any population. There has been a higher level of underreporting for dietary intakes observed in participants with higher Body Mass Index (BMI) (Thompson *et al*., 2001), in women (Sallé *et al*., 2006; Macdiarmid and Blundell, 1998), and in people with diabetes. Underreporting on food records is likely due to incomplete or inaccurate reporting due to participants' self-consciousness of recording consumed foods, which leads to dietary choices differing from "actual" usual dietary intake. Similarly, among older adults aged over 65, BMI and gender were indicators of underreporting with women more likely to underreport and men more likely to over-report energy intakes. An underestimation of dietary intakes was more common in older adults who were obese and overweight compared with those who had normal weights (Bazelmans *et al*., 2007). Under and/or overestimation of dietary intake is also associated with different types of foods. In one study, participants who were leaner and well-educated tended to over-reporting energy intake; the study also found participants who under reported energy intake had a tendency to over report bread, fruit and vegetable intakes; and under reported intakes of lollies and cheese (Bazelmans *et al*., 2007). In one validation study in older women, underreporting of energy intake was more likely than that of protein intake; there was also a greater tendency of underreporting energy intake in participants (older women living independently) with higher levels of physical activity (Visser *et al*., 1995, Thompson *et al.*, 2001). Most dietary assessment tools are prone to incomplete or under-reporting results. Taking this into account, some approaches may be required to overcome under-or over-estimations of dietary intakes when using a dietary assessment tool. For example, emphasizing the importance of accuracy and providing comprehensive training to participants before administration (Bazelmans *et al*., 2007, Cade *et al*., 2002).

2.4.2 Dietary variations

The typical diet among independent living older adults is difficult to measure due to the nature of dietary variations and dietary changes associated with ageing including poor oral health, declining metabolic rate, or loss of muscle strength. These factors can potentially masked the "true" dietary intake (Drewnowski and Evans, 2001). Furthermore, habitual dietary intake varies between individuals and within an individual (Willett, 2012). Studies of energy and nutrient variations in older women (50 to 69 years) suggests a greater variation in most nutrient intakes within an individual than between individuals. This study, however, compared older groups to younger groups and found smaller within-individual variation and between-individual variation in nutrient intakes of older participants (Fukumoto *et al*., 2013). This might be explained by the fact that older adults tend to have well-established dietary choices than younger adults. Dietary variations can be influenced by several factors including day-to-day variation, seasonal variation, food availability, and individual health conditions. In general, the longer the reference period, the smaller the seasonal variation should be. To overcome seasonal variation, a repeated FFQ should be administered over seasons to assess long-term dietary intake; a 24-hour recall or food record should be administered at different time points and be assessed across several days (Willett, 2012). Although statistically speaking, more days of assessment and more frequent administrations can help to better interpret the usual dietary intake due to smaller day-to-day and/or seasonal variations, realistic methods should be considered in epidemiological research to improve recruitment and respondent rates.

The day-to-day variation in dietary intake differs depending on the day of the week. It is important to understand these variations for appropriate long-term dietary assessments. Typically, the greatest dietary variation occurs between weekdays and weekends, for example, in one of the reviewed study, larger meals and more meat were consumed on weekend days than weekdays (Willett, 2012). The UK National Diet and Nutrition Survey (NDNS) suggested that dietary intakes on Saturday and Sunday may vary greatly from each other, therefore, assessing both weekend days may reduce bias and dietary variations (Willett, 2012; Whitton *et al*., 2011). The time intervals between the re-administrated assessments is also associated with the within-individual variation. Smaller within-individual variation was observed in middle-aged women when the recorded days were consecutive compared to administrations separated by several months (Cade *et al*., 2004; Cade *et al*., 2002).

2.4.3 Measurement error in older participants

In any dietary assessment research, it is inevitable for systematic and random errors to occur (Cade *et al*., 2004). Systematic errors include misreporting, under-and over-reporting, and inaccurately estimated portion sizes by participants. Assessing dietary intake in older adults can present the above errors and additional challenge due to impaired cognition. Some studies disqualify participants with cognitive dysfunction or impaired memory due to its limitation (less reliable data). But even with normal cognition, conducting longer FFQs among older adults may still be difficult for some participants to maintain focused and remain interested (Thompson *et al*., 2001), increasing the risk of measurement errors. These errors usually can be minimised with improved study design, trained interviewers/researchers, standardised instructions for participants, and ensuring the dietary assessment tool is age appropriate and population-focused (Willett, 2012).

2.4.4 Analysis of dietary intake

When estimating nutrient intakes from dietary assessment tools, a standardised food composition database is usually used as a source for nutrient contents. Food composition databases consist of food composites that are collated through laboratory analysis on the components of individual foods (Margetts and Nelson, 1997). As food composition databases are usually composed of foods that are most commonly consumed in a population, each country should have their own food composition database that is relevant to their population (Gibson, 2005). Differences between food databases are caused by several factors such as the existing natural variations between types of foods and within foods. For example, the selenium content of foods grown in New Zealand is lower than foods grown in Canada and the United States (high selenium levels in South Dakota) due to deficient selenium levels in the soil (Greenfield and Southgate, 2003). Furthermore, genetic modification of plants that involve changes of the plants' characteristics may affect its nutrient content due to added colour and/or biofortification. For instance, consumers in the US typically prefer darker orange carrots so marketers selectively increase the beta-carotene in carrots for a more saturated colour (Willett, 2012). In New Zealand, the New Zealand FOODFiles is the main food composition database currently available; it provides reliable nutrient values from foods commonly consumed in New Zealand (NZ Plant and Food Research, 2019). Changes to a food composition database may occur over time, for instance, greater diversity of the

population can increase the variety of foods available. Variations from food to food and from nutrient to nutrient exist between different food databases, especially in mixed dishes. To ensure optimal accuracy of measured dietary intakes, an up-to-date food database is recommended for use (Margetts and Nelson, 1997). There are some limitations in using food composition databases to obtain accurate dietary intake information, including missing foods and or nutrient values. These limitations need to be considered in the analysis of nutrient intakes (NZ Plant and Food Research, 2019; Gibson, 2005).

2.4.5 Selecting a dietary assessment method

In epidemiological studies, the selection of an appropriate dietary tool is largely dependent on the aim of the study, timeframe, and the research budget. Willet (2012) suggests that FFQs are more suitable for large population studies in comparison with food records and 24-hour recalls which requires extremely skilled interviewers. A self-administered FFQ allows the assessment of long-term dietary intake and is relatively inexpensive. An FFQ imposes less burden to both the participants and researchers. Researcher burden is also less profound due to improved completion/respondent rates with the use of an FFQ (Willett, 2012). A 24-hour recall is potentially less useful in assessing habitual dietary intakes of older adults who have impaired cognition and are usually more adept at long-term memory. However, self-administered dietary assessment tools or FFQs are not recommended in cognitively impaired participants (Thompson *et al*., 2001). One study did found however, that there were no significant associations between cognitive ability and the validity of an FFQ (Morris *et al*., 2003). A weighed food record is often perceived as the most accurate method for assessing dietary intakes, however, an FFQ is usually used to measure habitual intakes, short and accurate dietary intake measures may result in poor correlations to nutrient intakes (Sawaya *et al*., 1996). A self-administered FFQ is more commonly used in older adults and in large epidemiological research than other dietary assessment methods for assessing usual dietary intake (Morris *et al*., 2003; Willett, 2012).

2.5 Assessing the validity and reproducibility of a food frequency questionnaire

An FFQ should be validated in the population it is intended to be used to ensure it measures what it is proposing to measure. According to Willet (2012), validity refers to the degree to

which the questionnaires actually measure for the aspect of dietary intake it was designed to measure. Although there are various approaches to assess validity, often a more superior reference method is administered for comparison to validate an FFQ (Willett, 2012). In most FFQ validity studies, FFQs were compared against a food record between two days to four weeks or several 24-hour recalls collected between one to 28 days (Cade *et al*., 2002). If the FFQ is not validated for use, dietary assessments can result in false interpretations and lead to inaccurate statements of associations between diet and health outcomes.

Reproducibility refers to the consistency of two FFQs conducted on the same individual at different times. However, it needs to be acknowledged that results are unlikely to be identical on repeated administration (Willett, 2012, p. 97). Although reproducibility can reflect the performance of the FFQ, reproducibility may also vary due to dietary change within individuals over time. In addition to this, re-administered FFQ with very short time intervals is not recommended because participants are more likely to repeat their previous answers and render the validation purpose. However, longer time intervals may create greater dietary variations within individuals and reduce the FFQ reproducibility (Cade *et al*., 2002). Good validity may imply good reproducibility, but a dietary assessment tool with a good reproducibility does not necessarily indicate a good validity (Margetts and Nelson, 1997).

There are several considerations when assessing an FFQ validity and reproducibility in order to ensure the robustness of data. These factors are reviewed in the following sections including study population, sample size, reference methods and required recording days, the sequence of administration, and statistical analysis.

2.5.1 Study population

In any validation study, the dietary assessment tool is required to be up-to-date and appropriate for the population for which it is intended to be used. As reviewed by Cade *et al* (2002), the majority of validated FFQs were designed to be used by the general population. However, nearly one-third of FFQs were specifically designed and validated for use in populations with or at risk of a particular disease (Cade *et al*., 2002). Due to the nature of an FFQ, modifications can be made to an existing questionnaire to achieve new research purposes in a different population. Modified or newly developed FFQs should be validated before use, for similar reasons, an FFQ should be re-validated when used in a new population that is different from the previous study (Cade *et al*., 2004; Cade *et al*., 2002).

Validation studies from the Multi-Ethnic Cohort found correlations for energy adjusted nutrient intakes were similar among different ethnic groups when assessed using an FFQ and 24-hour recall (Stram *et al*., 2000). Similar results were observed in another study with reasonably high correlations in several nutrient intakes across ethnic groups (Willett *et al*., 1985; Willett, 2012; Cade *et al*., 2002). In one study in NZ, correlations varied between ethnic groups; higher correlations in nutrient intakes between two dietary assessment methods were observed in European compared with Polynesian groups (Metcalf *et al*., 1997). In theory, the more diverse ethnic groups for which an FFQ is intended, the greater variety of foods an FFQ should contain. According to Willett (2012) and Cade *et al* (2002), the FFQ response is usually prejudiced by participants' age, gender, ethnicity, education and health status. In addition to this, the food list in an FFQ should not be administered in a population with different types of diets, therefore, rendering the FFQ validity (Cade *et al*., 2002; Willett, 2012).

2.5.2 Sample size

According to most validation studies, a sample size of 100 to 200 is considered adequate to detect statistically significant correlations of interest for validity (Clover *et al*., 2007; Willett, 2012). A minimum of 50 participants is required if Bland-Altman statistics are to be used. Although it has been suggested when using correlation coefficients that at least 150 participants are required, such an assumption was based on a method where dietary assessment tool is measured against a food record more than 12 days to describe habitual dietary intake (Cade *et al*., 2002; Willett, 2012). If study uses a shorter reference method (short term dietary intake measures), a greater sample size is required to maintain the precision of correlation coefficients between the FFQ and other dietary assessment tools (Cade *et al*., 2002). However, correlation coefficients is not only influenced by the number of participants but also by the participants' food choices and their estimated portion sizes in the reference method (Willett, 2012; Cade *et al*., 2002). With the suggestion that studies preferably use 100 to 200 participants, there is a general consensus that the number of participants for FFQ validity studies does not required to exceed 200 (Cade *et al*., 2004).

2.5.3 Reference methods and recorded days required

One of the most crucial components in validating an FFQ is the selection of an appropriate reference method. A reference method should be able to provide optimal dietary estimates and not interfere with participants' habitual daily behaviour (Margetts and Nelson, 1997). Ideally, the reference method should have measurement errors independent of the FFQ, such as memory. If the measurement errors are independent, any lack of agreement between the two dietary assessment methods is more likely derived from dietary variations within individuals. As FFQs are used for assessing habitual dietary intakes, selecting a reference method that is short and precise, such as one 24-hour recall, can accidentally result in poor correlations between two dietary assessment methods and render the validity (Cade *et al*., 2002; Margetts and Nelson, 1997).

With the above considerations, food records have been widely adopted in many validation studies. Although it is impossible to measure dietary intake with no errors by any dietary assessment method, food records are able to accommodate a wide range of dietary intakes and frequencies of food consumption over several days. A 24-hour recall may have sources of errors correlated with those of an FFQ as they both rely on memory. For populations with low health literacy, a 24-hour recall may be more useful and appropriate than a food record. In theory, repeats of 24-hour recalls may be administered as the reference method; multiple 24-hour recalls would be similar to a food record. However, recalls often rely heavily on memory and can contribute to loss of validity. From a study point of view, dietary recalls are relatively costly and timely compared to a self-administered food record; 24-hour recalls also require skilled interviewers to complete the dietary intake assessment (Cade *et al*., 2002).

Increasing the number of days recorded in the dietary assessment reference methods may improve the validity of the tested methods, as more recorded days can assess longer habitual intake which better correlates to the information gathered from an FFQ. With an appropriate sample size, the sufficient number of days of food records to capture the "true" usual dietary intake, typically range from 14 to 28 days (Cade *et al*., 2002). However, a reduction of recorded days can improve study recruitment and completion. Based on respondent rates, participants' burden appears to be a trade-off for the number of recorded days. In recent years, the National Diet and Nutrition Survey study in the UK has reduced the required days of seven to four days for food records (Ziauddeen *et al*., 2017). Furthermore, Stram (1995)

suggested that in most settings, the optimal study design rarely requires more than four or five days of food records (Stram *et al*., 1995).

Many validation studies have adopted isotope and biochemical techniques over other dietary assessment methods. Biochemical methods such as doubly-labelled water, urinary nitrogen balance, or vitamin C can reflect the latest dietary intake. The use of biomarkers from blood and tissue samples can avoid measurement errors dependent on the tested method. Biomarkers are also less affected by problems such as poor cognitive function and mis-or under-reporting of dietary intake (Willett, 2012; Cade *et al*., 2002). However, biomarkers are typically invasive and expensive. In addition to this, each biomarker is nutrient specific so validation studies often focus on one nutrient at a time. To compare with a dietary assessment method, the period of nutrient intake measured by a biomarker should be the same as the dietary assessment method. This can be a difficult factor to control due to the effects of absorption and excretion. Similarly, the influences of food digestion, absorption, and metabolism which differ in each individual may have an impact on the "true" nutrient intake. Another potential challenge in assessing nutrient intake by biomarkers is the existing errors within the biochemical techniques which greatly depends on the type of biomarker used as the reference method (Gibson, 2005; Margetts and Nelson, 1997).

2.5.4 Sequence of administration

In most validation studies, the reference method was administered after the test method and the mean time intervals between administrations was 25 to 28 days (Nelson *et al*., 1997). The main goal is to avoid participants repeating the exact same dietary intake afterwards and misrepresenting the validation. This is because when the reference method is completed after the test method, the participants may have an increased awareness of their diets and pay additional attention to recreate a similar dietary pattern or intake in latter dietary reports. As a result, this could unintentionally increase the agreement for nutrient intakes between the test and reference method (Nelson *et al*., 1997; Cade *et al*., 2002). Taking these factors into account, Willett (2012) suggested re-administering the FFQ twice, both prior to and after the reference method. The mean dietary intake from both FFQs can then be used against the reference method for validation. Alternatively, a random selection of one of the FFQs is used for comparison with the reference method (Willett, 2012). However, research design should always consider the practicality and budgetary of any methodology when validating an FFQ.

2.6 Statistical analysis of validation and reproducibility

There is no consensus agreement on the most accurate statistical method to validate a dietary assessment tool. In theory, a combination of statistical approaches is recommended for validating an FFQ (Cade *et al*., 2002; Masson *et al*., 2003). A range of statistical methods used in validation studies are reviewed below.

2.6.1 Correlations coefficients

The most common statistical technique, used in 83-90% validation studies is the correlation coefficients; including Pearson, Spearman, intra-class, and method of triads. Based on the data distribution, either the Pearson's or Spearman's correlation coefficients (Spearman's is used for non-normal distributed data) are selected for analysis (Cade *et al*., 2002).

For validity, correlations below 0.3 or 0.4 indicate low levels of agreement between two dietary assessment methods (Cade *et al*., 2004). Willet *et al* (2012) suggested that correlation values that reach 0.6 to 0.7 represent solid evidence of an agreement between an FFQ and a food record, but values above 0.8 or 0.9 are statistically unlikely. The general accepted correlations for assessing reproducibility range from 0.5 to 0.7 (Hopkins *et al*., 2009; Willett, 2012). Although correlation coefficients are widely used in the majority of validation studies, this method does not measure the "true" agreement between the two dietary assessment methods, and only the degree of association. High correlations, therefore, do not necessarily guarantee good agreement between the dietary assessment methods (Willett *et al*., 1985; Bland and Altman, 1986). As Masson (2003) suggested, validation studies should use both the correlation coefficients and cross-classification with weighted kappa statistic (Masson *et al*., 2003). If the study aim is to assess the agreement between the dietary assessment methods, the intra-class correlation may be more helpful to use as it reflects both the level of correlations and disagreements between FFQs (Margetts and Nelson, 1997). Furthermore, Bland and Altman (1999) noted that some degree of correlation already exists between two methods that measure the same content, thus negative correlation is very unlikely to occur. Due to their disadvantages, correlation coefficients should be used alongside other statistical methods. However, considering their popularity, using correlation coefficients may allow comparison across other validation studies (Bland and Altman, 1999).

2.6.2 Paired t-test and Wilcoxon signed-rank test

The comparison of groups' means between two dietary assessment methods is important to sufficiently evaluate the test method, especially when absolute nutrient intakes are assessed. This can be achieved by paired t-tests on normally distributed data, which can determine the mean difference between two sets of data (Cade *et al*., 2002). Nevertheless, when dietary intakes are significantly different from a normal distribution, Wilcoxon signed-rank test is more appropriate for use (Gibson, 2005). However, the comparison of means (nutrient intakes) between an FFQ and food record does not establish adequate validation. This method fails to rank the nutrient intake from each individual across the distribution, thus does not provide information on its ability to correctly classify participants by dietary intakes (Block and Hartman, 1989).

2.6.3 Cross-classification and weighted kappa statistic

Cross-classification is used to rank participants by dietary intakes from both an FFQ and a reference method, the ability to rank nutrients can be assessed by comparing these categorised groups (Gibson, 2005). A comparison of the participants' categories (in quintiles, quartiles, or tertiles) may illustrate whether participants' nutrient intakes assessed by two methods are in the same category or not. To rank nutrients in cross-classification, participants who fall into the same category classification from both dietary assessment methods are presented as "correctly classified"; participant who fall into the opposite category classification are presented as "grossly misclassified". In theory, the desired agreement in validity studies using tertiles in cross-classification is at least 50% of participants being correctly classified and less than 10% being grossly misclassified. However, the percentages will also include agreements that could be accounted for by chance (Masson *et al*., 2003; Willett *et al*., 1985).

Therefore, the weighted kappa statistic is recommended to be used in conjunction with cross-classification. The weighted kappa can be useful as it is a summary measure of cross-classification, and may adjust the agreement expected by chance and the degree of misclassification. However, the weighted kappa statistics is dependent on the number of categories used (Cohen, 1968).

2.6.4 Bland-Altman analysis

The Bland Altman analysis is used as a visual representation of the agreement for nutrient intakes between the FFQ and the reference method. The scatter plots show the mean difference for each nutrient versus the mean nutrient intake from the two methods. Obvious outliers and trends for increased nutrient intakes can be easily examined (Bland and Altman, 1999). The Bland-Altman method can be used to measure the level of potential bias by calculating the limits of agreement (LOA) between the difference and mean intake of nutrient intakes. The LOA is calculated by the mean difference in the nutrient intakes ± 1.96 standard deviation (Bland and Altman, 1999). The width of the LOA demonstrates the level of two dietary assessment methods in producing equal systematic results; the narrower the LOA is, the stronger the agreement is (Bland and Altman, 1999; Cade *et al*., 2004).

2.6.5 Linear regression analysis and Bland-Altman plots

Regression analysis was undertaken by four percent of the studies reviewed by Cade (Cade *et al*., 2004; Cade *et al*., 2002). Linear regression is often used alongside Bland-Altman plots to measure the level of agreement. Ideally, the result should be non-significant. A statistically significant result (p-value <0.05) indicates an assumption of proportional bias among the variables and that the difference between the two methods is dependent on the mean intake (creates a trend and/or dependence on the variable) (Bland and Altman, 1999). In general, regression is used to predict the value of the outcome variable by using the predictor variable, whereas, correlation is often used to measure the strength of the associations between variables. Both correlation and regression are suggested to be used alongside the Bland-Altman plots and not as a replacement method (Cade *et al*., 2002; Cade *et al*., 2004)

2.6.6 Energy adjustment of nutrient intakes

Energy adjustment is based on the assumption that individuals who self-report dietary intakes tend to under-or mis-report food intakes in a similar way; energy adjustment is especially helpful to correct measurement errors in nutrients that comprise a proportion of energy intake (Kipnis *et al*., 1997). Another rationale for energy adjustment is to account the fact that energy expenditure and requirements vary depending on body size, metabolic rate, and physical activity (Rhee, *et al*., 2014; Willett *et al*., 1997). As these assumptions are

reasonable, energy adjustment becomes beneficial for data analysis of dietary intake related to health and disease (Cade *et al*., 2002). Energy adjustments can minimise potential bias and increase the correlation coefficients for nutrient intakes between the test method and reference method (Willett *et al*., 1997). Margetts *et al* (1995) suggests that an FFQ needs to be comprehensive enough to measure energy intakes when energy adjustment is performed. It is important to understand when to adjust nutrients for energy intakes and which methods are most appropriate for use (Margetts and Nelson, 1997; Cade *et al*., 2004). In most validation studies from the reviewed literature, correlations have improved for most nutrients after adjusting nutrient intakes for energy intakes (Sam *et al*., 2014; Bell, *et al*., 1999; Beck *et al*., 2018). The nutrient density model is commonly used to adjust nutrients for total energy intake whereby nutrient intake is expressed as amount per 1000 kilocalories (or per 1000 kilojoules). Other energy adjustment methods include standard multivariate, nutrient residual, and the energy partition model (Willett *et al*, 1997).

2.7 Food frequency questionnaires developed internationally for older adults

Internationally large epidemiology studies are investigating associations between dietary intakes and health outcomes in older adults using food frequency questionnaires. This section will investigate validation and reproducibility studies of food frequency questionnaires developed or adapted for older adults living overseas. These studies may provide insights into the validation process for critical comparison (Table 2.2). This review focuses on validation studies which have compared food groups and/or nutrient intake from an FFQ against a reference method such as a food record or 24-hour recalls. Studies that use biomarkers as the reference method have been excluded.

All of the reviewed validation studies have compared mean dietary intakes between assessment methods and used correlation coefficients; three out of ten studies used cross-classification (quintile or quartiles); two studies used the kappa and/or weighted kappa statistics and only one study used Bland-Altman plots alongside cross-classification and correlation coefficients for nutrient analysis (Table 2.2). Cade *et al* (2014) and Willet *et al* (2012) have suggested to use a combination of methodologies for statistical analysis due to the limitation of correlation coefficients. Although, correlations are widely used among validation studies to measure the degree of associations, correlations fail to measure the "true" agreement between two dietary assessment methods (Willet *et al*., 2012; Cade *et al*.,

2014). Among the reviewed studies, validity correlations varied greatly across macronutrients; low to moderate correlations were observed for total fat, polyunsaturated fat, monounsaturated fat, and cholesterol from non-attenuated nutrient intakes and ranged between 0.07 and 0.40 (Carithers *et al.*, 2009; Boucher *et al.*, 2006; Morris *et al*., 2003). Another study found moderate to high correlations (r>0.40) for all macronutrients except for protein (0.18) (Smith *et al.*, 1998). On the other hand, moderate to high correlations were commonly observed for carbohydrate and alcohol ranging from 0.41 to 0.83. One possible reason for this may be because foods classified as carbohydrates are often served as staple foods on a daily basis, therefore, participants were more familiar with quantifying portions of these foods compared to foods which contribute to other macronutrient intakes (Smith *et al.*, 1998; Morris *et al*., 2003; Klipstein-Grobusch *et al*., 1998; Corrente *et al.*, 2013).

The lowest validity correlations were commonly observed for micronutrients including β-carotene, retinol, vitamin A, and folate with correlations ranging between 0.10 and 0.38 (Smith *et al*., 1998; Malekahmadi *et al.*, 2016; Carithers *et al*., 2009; Boucher *et al*., 2006). The highest validity correlations were commonly observed for thiamine, vitamin C, calcium, magnesium and phosphorus (Klipstein-Grobusch *et al.*, 1998; Morris *et al*., 2003; Smith *et al*., 1998; Watanabe *et al*., 2019).

The statistical variations in correlations may also vary across gender, education, health status, and health literacy (Carithers *et al*., 2009). Although men were found to have lower validity correlations and higher reproducibility correlations than women in a US study (Morris *et al*., 2003), other evidence found no significant difference in correlations by genders (Mares-Perlman *et al*., 1993). Similarly, no remarkable differences were observed in validity and reproducibility correlations between ethnic groups (Morris *et al*., 2003, Mares-Perlman *et al*., 1993).

Studies which have assessed reproducibly all had correlations above 0.4 for total energy and macro-and micro-nutrients, with most correlations falling between 0.50 and 0.70 (Smith *et al*., 1998; Malekahmadi *et al*., 2016; Morris *et al*., 2003). While most studies focused on the validity of FFQs, reproducibility was often measured using intra-class or Pearson's correlations alone in five of the ten studies reported in Table 2.2. Other statistical methods should be used to assess reproducibility since correlations may have already exist between the same dietary assessment methods at different administration times, therefore, strong correlations between two FFQs is expected (Bland and Altman, 1999; Willet, 2012).

Table 2.2 Validity studies for FFQs in older adults internationally

Reference	Country	Target population	FFQ design	Study method	Findings
Mares-Perlman *et al*. (1993)	United States	211 participants, females and males, 43-83 y from the Beaver Dam Eye study.	124-item FFQ, modified version of the National Cancer Institute diet history questionnaire.	FFQ compared against a 2-day FR to assess validity. FFQ re-administered (3 months interval) to assess reproducibility.	Validity – correlations for nutrients without supplements ranged from 0.06 (iron) to 0.80 (alcohol). Reproducibility – correlations ranged from 0.50 to 0.90.
Smith *et al*. (1998)	Australia	152 participants, females and males, 63-80 y attending a community based eye study in Sydney.	145-item FFQ modified from the Willett FFQ for the Australian diet and vernacular health. Foods rich in fats, vitamin C and beta-carotene added. 9 frequency options and standard portion sizes provided.	Self-administered FFQ compared against a re-administered FFQ 15 month later to assess reproducibility; compared against a 3 or 4DFR to assess validity.	Validity - correlations for energy adjusted nutrients ranged from 0.10 (zinc) to 0.79 (alcohol). Reproducibility - correlations for nutrients ranged from 0.60 to 0.80 in both short (1 month later) and long-term (12-18 months).
Klipstein-Grobusch *et al*. (1998)	Netherlands	80 participants, females and males, 55-75 y in a community based prospective cohort study in Rotterdam.	170-item semi-quantitative FFQ adapted for use in the elderly.	FFQ compared against a 2 or 3DFR (depending on intervention period and control group used) collected over 1 year to assess validity.	Validity - Pearson's correlations for energy and all nutrients ranged from 0.49 (saturated fat) to 0.88 (water) for crude data (mean 0.65). Correct classification into same quintiles ranged from 26.3 to 75.0% for energy adjusted nutrients.
Morris *et al*. (2003)	United States	232 participants, 118 Black and 114 White randomly selected participants from the Chicago Health and Ageing Project, females and males, 68–99 y.	Modified version of the Harvard FFQ measuring usual intake in the past year of 139 food items and vitamin and mineral supplements.	FFQs completed at month one and twelve to assess reproducibility. Completed multiple 24-hr recall interviews (mean = 3.6) over 12 months to asses validity.	Validity - Pearson’s correlations ranged from 0.31 (protein) to 0.67 (vitamin E with supplements), with a mean of 0.46. Reproducibility - Intra-class correlations ranged from 0.50 (vitamin B12) to 0.70 (folate).

Reference	Country	Target population	FFQ design	Study method	Findings
Boucher *et al*. (2006)	Canada	166 females, 25-74 y sampled from random population.	126 item FFQ modified from Block's full-diet FFQ developed in 1998 by the US National Cancer Institute. Canadian relevant foods included.	FFQ1 compared against two 24-hr recalls to assess validity; FFQ administered twice approximately 56 days apart to assess reproducibility.	Validity - de-attenuated Pearson correlations ranging from 0.11 to 0.73 (macronutrients) and 0.50 to 0.76 (micronutrients with supplements). A median of 0.59. Reproducibility - correlations ranged from 0.57 to 0.90 (macronutrients) and 0.65 to 0.88 (micronutrients with supplements), a median of 0.75.
Carithers *et al*. (2009)	United States	499 participants from the Jackson Heart Study, females and males, 35-81 y.	Delta NIRI 283-item FFQ, dietitian administered, with 4 portion size options, designed to assess full dietary intake.	FFQ compared against four 24-hr recalls one month apart to assess validity.	Validity - Pearson correlations for energy adjust nutrients in men ranged from 0.21 (PUFA) to 0.64 (magnesium); in women ranged from 0.16 (vitamin A) to 0.59 (magnesium).
Eysteinsdottir *et al*. (2012)	Iceland	128 healthy participants, females and males, mean age 74 y ± 5.7.	AGES-FFQ divided into three parts, containing questions on early life diet (14-19 y), midlife diet (40-50 y) and current diet. 30 questions with 7 frequency options.	FFQ compared against a 3-day weighed FR two weeks apart to assess validity.	Validity - correlations for all food items ranged from 0.01 to 0.71. Correlations in females for rye bread, oatmeal/muesli, raw vegetables, candy, dairy products, milk, pure fruit juice, cod liver oil, coffee and tea ranged from 0.40 to 0.61. Correlation for fish topping/salad, fresh fruit, blood/liver sausage, whole-wheat bread, and sugar in coffee/tea ranged from 0.28 to 0.37.
Corrente *et al*. (2013)	Brazil	73 participants, females and males, mean age 71.5 y.	67-item FFQ, 4 choices of food serving sizes, designed to estimated micro and macronutrient intake.	FFQ compared with three 24-hr food recalls (baseline, 2nd recall the coming weekday, then weekend for 3rd recall) to assess validity.	Validity - correlations for unadjusted macronutrients ranged from 0.58 to 0.66; micronutrient 0.52 (calcium) to 0.75 (folate). Kappa values ranged from 0.18

Reference	Country	Target population	FFQ design	Study method	Findings
					to 0.37. Weighted kappa values ranged from 0.37 to 0.50.
Malekahmadi *et al*. (2016)	Iran	185 participants, females and males from random selected population, 60-75 y.	89-item FFQ with portion sizes, designed to assess antioxidant intakes in older adults and vulnerable populations.	FFQs completed and re-administered 3 months later to assess reproducibility. A 2-day FR completed alongside FFQ2 to assess validity.	Validity - correlations in five energy unadjusted micronutrients ranged from 0.38 (carotene) to 0.55 (selenium); energy adjusted micronutrients 0.38 (carotene) to 0.55 (selenium). Reproducibility - Intra-class correlations ranged from 0.47 (vitamin E) to 0.62 (vitamin C).
Watanabe *et al*. (2019)	Japan	143 participants, females and males, 65-88 y from a subpopulation of the Kyoto-Kameoka study.	46-item FFQ designed for the middle aged general population to assess energy and multiple nutrient intakes.	FFQ compared against a 7DFR completed one year after the baseline to assess validity.	Validity - median correlation coefficients (Spearman) for energy and nutrient intakes was 0.24, ranging from 0.01 to 0.40. Macronutrient: ranged from 0.08 (total fat) to 0.40 (energy). Micronutrient: ranged from 0.01(n-6) to 0.40 (vitamin B6).

2.8 Food frequency questionnaires available for older New Zealanders

There have been a small number of FFQs developed to assess multiple nutrient intakes for the population in NZ and have been validated (Table 2.3). However, validated FFQs specifically developed for older New Zealanders is limited to one (Horwath, 1993). The reviewed validation studies in NZ cover a wide range of age groups (20 to 75 years old) in both genders. From the reviewed studies, one study used correlation coefficients alone and five other studies used other additional statistical measures, such as cross-classification (Sharpe *et al*., 1993; Sam *et al*., 2014; Beck *et al*., 2018). While correlation coefficients are widely used to assess FFQ validity and/or reproducibility, most studies in New Zealand used other statistical methodologies as recommended (Cade *et al*., 2002; Willett, 2012) to measure the associations between the FFQ and the reference method (Table 2.3).

The FFQ from Horwath developed for older adults was validated on a small population (n = 53) nearly 30 years ago (Table 2.3). Horwath (1993) reported 13 macro-and micro-nutrients in women and 16 in men with validity correlations above 0.40. In men, the highest correlation (0.78) was observed for protein and in women the highest correlation (0.66) was observed for saturated fat (Horwath, 1993). In the general population, the highest validity correlations for macronutrients were observed for cholesterol, and alcohol; ranging from 0.48 to 0.68 (Sam *et al*., 2014; Bell *et al*., 1999; Horwath, 1993). Lower macro-nutrients validity correlations were observed for carbohydrate, sugar, total fat, polyunsaturated fat, and dietary fibre; ranging from 0.06 to 0.37 (Sam *et al*., 2014; Metcalf *et al*., 1997; Bell *et al*., 1999). The highest micronutrient correlations in these studies were observed for β-carotene, vitamin B12, C, and calcium; ranging from 0.36 to 0.74 (Sam *et al*., 2014; Bell *et al*., 1999; Horwath, 1993). Lower validity correlations for micro-nutrients were observed for vitamin A, E, thiamine, folate, and selenium (Bell *et al*., 1999; Sam *et al*., 2014). Of the two studies that assessed reproducibility between FFQs had correlations at least 0.40 for total energy and nutrients; ranging from 0.40 to 0.80 (Sam *et al*., 2014; Metcalf *et al*., 1997).

Similar to validation studies from overseas, under-reporting was commonly observed. Metcalf *et al* (1997) found Europeans were more likely to under-report energy intake from the FFQ than Māori and Pacific Islanders, whereas Pacific Islanders tended to overestimate energy intakes from the FFQ. From food records, Māori and Pacific Islanders tended to under-report energy intakes compared to people of European ethnicity. However, under-reporting energy intakes from food records was associated with overweight/obesity in all

ethnic groups (Metcalf *et al*., 1997). Greater levels of under-reporting energy intake were also observed in Samoans who were obese (BMI>30 kg/m^2) than those who were non-obese (Bell *et al*., 1999). The phenomenon of under-reporting was commonly observed in populations with higher BMI regardless of gender, ethnicity, and age (Bell *et al*., 1999; Metcalf *et al*., 1997).

In one study, validity correlations varied by ethnicities between the FFQ and the reference method; Europeans had higher validity correlations ranging from 0.41 to 0.84, whereas in Māori and Pacific Islanders correlations ranged from 0.36 to 0.56. Researchers suggested that the variation between ethnic groups may due to different cultural backgrounds and in some cases, English being the second language (Metcalf *et al*, 1997). This may have resulted in different perceptions of portion size and types of food consumed. For reproducibility, there were no significant differences in correlations between the FFQs by ethnicity (Metcalf *et al*., 1997; Bell *et al*., 1999).

The studies that adjusted nutrient intakes for energy intakes appeared to reduce errors and improved validity correlations especially for nutrients contributing to energy intake (Bell *et al*., 1999; Sam *et al*., 2014; Beck *et al*., 2018). From the reviewed literature, energy adjustment was based on a reasonable assumption where most participants tend to under-or mis-report dietary intake in a similar way, particularly from self-reported dietary assessment methods. This residual method, energy adjustment can control the confounding effect of energy intakes and improve data quality (Willett *et al*., 1997).

Table 2.3. Validity studies of FFQs in adults and older adults in New Zealand

Reference	Target population	FFQ design	Study method	Findings
Horwath. (1993)	53 healthy, females and males, 54-86 y, living independently in Dunedin.	120-item FFQ including cooking methods and food preparation. Additional questions regarding salt and fat intake.	FFQ compared against a 2-day FR two weeks apart to assess validity.	Validity - Differences in mean intakes between the FFQ and FR for most nutrients were less than 5%. Correlations (excluding supplements) ranged from 0.34 (zinc) in women to at least 0.75 (protein, zinc and calcium) in men.
Sharpe *et al*. (1993)	102 participants, females and males, 25-75 y, living in North Island.	75-item FFQ designed for cardiovascular risk assessment, with 6 frequency options and 4 portion sizes.	FFQ compared against a 7-day FR completed over 2 weeks, both administered at the same time to assess validity.	Validity - Correlations for macronutrients ranged from 0.55 (fibre) to 0.70 (saturated fat). Correlations for micronutrients ranged from 0.21 (vitamin A) to 0.65 (calcium), 0.71 (alcohol). Cross-classification: Correct classification ranged from 35% (β-carotene) to 75% (caffeine), and gross misclassification ranged from 0% (at least 50% of nutrients) to 10% (protein and potassium).
Wilson *et al*. (1996)	58 Caucasian women 25-49 y, living in Dunedin.	Short FFQ to measure dietary calcium intake.	Calcium FFQ compared against a 7-day estimated FR to assess validity.	Validity – Cross-classification: 81% of participants correctly classified into the same or adjacent quartiles; 3% were grossly misclassified.
Metcalf *et al*. (1997)	176 participants, females and males, 40-65 y, 124 European and 52 Polynesian (NZ European, Māori, and Pacific Islanders).	142-item FFQ with published portion size.	FFQ completed and compared against a 3-day FR (36 months intervals) to assess validity. Repeated FFQ (36 months intervals) to assess reproducibility.	Validity – Correlations ranged from 0.41 (total fat) to 0.84 (alcohol) in Europeans; 0.36 (fibre) to 0.56 (alcohol) in Polynesians. Under-reporting in FR correlated to obesity in both ethnic groups. Reproducibility - Correlations ranged from 0.41 (calcium) to 0.83 (alcohol) in Europeans; 0.47 (MUFA) to 0.88 (alcohol) in Polynesians.
Bell *et al*. (1999)	55 Samoan, females and males, mean age 43 ± 14 y.	89-item quantitative FFQ, standard portion size designed to assess usual dietary intake, expanded from the Willett FFQ.	FFQ compared against 7-day FR collected over 3 months to assess validity.	Validity – Correlations ranged from -0.03 (thiamine) to 0.48 (vitamin B12). Correlations for energy adjusted macronutrients ranged from -0.05 to 0.28 and -0.12 (vitamin B6) to 0.54 (calcium) for micronutrients. Correct classification ranged from 29 to 44%; gross misclassification ranged from 9 to 22%.

Reference	Target population	FFQ design	Study method	Findings
Sam *et al*. (2014)	132 participants, females and males, 30-59 y.	154-item FFQ, with 7 frequency options to assess multiple nutrients in diet.	Completed FFQ compared against four 2-day FRs over 12 months (2 weeks, 3 months, 6 months, and 9 months intervals) to assess validity.	Validity - Correlation coefficients for energy-adjusted nutrients ranged from 0.24 (zinc) and 0.28 (calcium) to 0.58 (β-carotene). Unadjusted nutrient correlations ranged from 0.11 (calcium) to 0.50 (selenium). Correct classification in unadjusted nutrients ranged from 66 to 97%; gross misclassification ranged from 0.8 to 12%. Reproducibility - Correlation coefficients ranged from 0.47 (calcium) to 0.83 (alcohol), with most values falling between 0.60 and 0.80.
Beck *et al*. (2018)	110 women of Māori, Pacific or European ethnicity, 16–45 y.	220-item women's FFQ to assess multiple nutrients in diet.	FFQ compared against a 4-day weigh FR to assess validity.	Validity - All nutrients were overestimated except alcohol. Energy adjusted correlations ranged from 0.23 to 0.67 (mean 0.48) and unadjusted ranged from 0.11 (iron) to 0.59 (saturated fat). Correct classification into same or adjacent quartiles was over 70% for all energy adjusted nutrients except folate and vitamin D.

2.9 Summary

From the reviewed studies, Horwath (1993) was the only validated FFQ specifically designed for older adults in New Zealand. The study, however, was validated on a small population (n = 53) living in Dunedin nearly 30 years ago (Horwath, 1993). Because dietary intake and food availability can change over time and place, an FFQ should be developed and validated according to the current population and diet (Willett, 2012; Nelson, 1997).

Few studies have used other statistical methods in addition to correlation coefficients to assess FFQ validity, in fact, many studies used correlation coefficients alone (Boucher *et al*., 2006; Morris *et al*., 2003; Eysteinsdottir *et al*., 2012). However, given the limitation of correlation coefficients, other statistical methods such as cross-classification, kappa statistics, and Bland-Altman analysis should be used alongside to assess the validity and/or reproducibility of an FFQ. Furthermore, an appropriate sample size is required in studies to ensure the sample is representative of the population (Cade *et al*., 2002). From a statistical point of view, if sample size is inadequate, correlation coefficients becomes less precise with loss of power to detect the significance between dietary assessment methods (Thompson and Subar, 2001). In conclusion, validation studies should avoid using correlation coefficients alone given their limitations to assess "true" agreement between dietary assessment tools.

While FFQs have been validated in New Zealand adults (Metcalf *et al*., 1997; Wilson & Horwath, 1996; Sam *et al*., 2014), an up-to-date, age-appropriate, valid and reproducible semi-quantitative FFQ for older New Zealanders to assess multiple nutrient intakes is warranted. A validated FFQ would be of value for future studies for older adults in NZ assessing associations between dietary intake and health outcomes.

Chapter Three: Research Manuscript: Determining the Relative Validity and Reproducibility of a Food Frequency Questionnaire to Assess Nutrient Intake in Older Adults in New Zealand

Angela D Yu[1], Dr Cathryn A Conlon[1], Dr Kathryn L Beck[1]

[1]School of Sport, Exercise and Nutrition, Massey University, Auckland 0632, New Zealand; J.Yu2@massey.ac.nz; C.Colon@massey.ac.nz; K.L.Beck@masseyac.nz

3.1 Abstract

Background: The population of New Zealand is ageing. Dietary intake in older adults is an important predictor of health and disease outcomes, however, few dietary assessment tools are available for measuring dietary intakes in older adults. To the best of our knowledge, there is no current validated food frequency questionnaire (FFQ) available for measuring multiple nutrient intakes in older New Zealanders.

Aim: To evaluate the relative validity and reproducibility of a semi-quantitative food frequency questionnaire for assessing nutrient intake in older adults aged living in New Zealand.

Methods: Participants were a convenience sample of older New Zealanders aged 64 to 75 years who completed a 109-item self-administered FFQ at baseline (FFQ1) and four weeks later (FFQ2) to assess reproducibility. FFQ1 was compared against a four-day food record (4DFR) completed between administrations of FFQs to determine the relative validity. Agreement between the dietary assessment tools was assessed using paired t-tests, correlation coefficients, cross-classification with the weighted kappa statistic, Bland and Altman plots, and linear regression analysis. Nutrients were adjusted for energy intake and were assessed by the same statistical methods.

Results: Energy adjustments moderately improved the relative validity and reproducibility for most nutrients. Validity correlation coefficients for the energy and energy adjusted nutrients between the FFQ and 4DFR ranged from 0.05 (selenium) to 0.76 (alcohol), with a mean of 0.35. Validity correlations above 0.40 were observed for at least 12 nutrients. Correct classification for energy adjusted nutrients ranged from 33.1% to 68.1% (mean 47%) and gross misclassification ranged from 3.0% to 20.5% (mean 12.6%). Weighted kappa statics for

energy adjusted nutrients ranged from 0.04 (folate) to 0.61 (alcohol). Reproducibility correlations for energy adjusted nutrients ranged from 0.30 (vitamin A) to 0.91 (alcohol), with most correlations between 0.60 and 0.80. For reproducibility, correct classification ranged from 52.7% to 78.1% with a mean of 60%; gross misclassification ranged from 1.3 to 6.6% (mean 4.8%). Weighted kappa statistics for energy adjusted nutrients ranged from 0.38 (iodine) to 0.74 (alcohol).

Conclusion: The FFQ appears to have reasonable relative validity and good reproducibility for ranking nutrient intakes in older New Zealanders. The FFQ could be used in future research to measure relative nutrient intakes in older adults but is not suitable for assessing absolute nutrient intake.

Keywords: Food questionnaire; evaluate; dietary assessment; food diary; validation; reliability; elderly; macronutrient; micronutrient

3.2 Introduction

New Zealand's population is ageing. The proportion of adults aged 65 years and over is expected to reach 26% by 2051 (Fletcher and Lynn, 2002). As life expectancy increases, people are living longer but not necessarily in good health. Furthermore, physiological changes associated with natural ageing and nutrition-related disease increase healthcare costs and hospitalisation (Cornwall & Davey, 2004; Stefanogiannis *et al*., 2005). In New Zealand, older adults aged 65 to 74 years carry a heavier burden of chronic diseases such as coronary heart disease, bowel cancer, musculoskeletal disorders, with vascular disease being the main cause of health loss (Ministry of Health, 2016).

In an ageing population, suboptimal intake of both macro- and micro-nutrients is a concern (van Dronkelaar *et al*., 2018). For example, suboptimal calcium and vitamin D intake is commonly observed in older adults (aged 65 and over); insufficient dietary intakes may contribute to bone loss and a higher risk of fractures (Hughes *et al*., 1997; Lips, 2001). Inadequate dietary protein in adults over 60 years is associated with higher risks of sarcopenia and muscle wasting, as insufficient intakes may result in protein deficiency and cause changes in the body composition (Yang *et al*., 2019).

As dietary intake is closely associated with the health and wellbeing of a population, it is important that dietary intake is properly assessed (Schulze *et al*., 2018; van Dronkelaar *et al*.,

2018). However, it is challenging to assess typical dietary intake from a population, especially in older adults, for example, due to declining cognition. The complications may include dietary changes associated with the ageing process. Although, dietary intakes and habitual behaviours are likely more established in older adults compared to younger populations, dietary intakes can be affected through adulthood by poor oral health, taste changes, poorer muscle strength and declining metabolic rates (Drewnowski and Evans, 2001). Therefore, a robust and validated FFQ which assesses a range of nutrient intakes specifically in older adults is warranted.

Traditionally, a weighed or estimated food record (usually self-administered where the foods consumed are recorded over a period of time) is used as the golden standard for assessing dietary intake (Cade *et al*., 2002). However, these dietary assessment methods are less practical in epidemiology research involving large populations. In comparison, a food frequency questionnaire (FFQ) is relatively easy to complete, inexpensive and is readily computerized so achievable for large sample size (Willett, 2012). With an FFQ, participants are presented with a lists of food items and answer how frequently each food item is consumed (Cade *et al*., 2004). Although an FFQ is less useful in measuring absolute dietary intakes, a validated FFQ can reflect the typical diet and relative nutrient intakes of a population and allows researchers to identify regionally and locally relevant dietary risks (Haftenberger *et al*., 2010; Willett, 2012). Prior to being used, an FFQ should be assessed for validity by testing against a reference method such as a biomarker or another dietary assessment tool, such as a food record. Validation can help to ensure the FFQ measures what it intends to measure. As inaccuracies may lead to incorrect interpretations regarding associations between dietary intakes and health outcomes (Cade *et al*., 2002). An FFQ should be re-administered to measure the reproducibility of the FFQ. Assessing reproducibility ensures the FFQ is capable of reproducing the same results at a different point of time while acknowledging that two results would never be identical (Cade *et al*., 2002; Miller *et al*., 2010).

While FFQs have been validated in New Zealand adults (Beck *et al*., 2012; Ingram *et al*., 2012; Wilson & Horwath, 1996; Sam, Skeaff, & Skidmore, 2014), an up-to-date, valid and reproducible FFQ for use in New Zealanders of older age to assess multiple nutrient intakes is not available. To our best knowledge, the only validated FFQ study in older adults was conducted nearly 30 years ago and focused mainly on calcium intake in 53 older adults living in Dunedin (Horwath, 1993).

The aim of this study is to evaluate the relative validity and reproducibility of a semi-quantitative FFQ by assessing relative nutrient intake in older adults aged 65 to 74 years living in New Zealand.

3.3 Materials and methods

The FFQ validation and reproducibility study was undertaken as part of the REACH (Researching Eating, Activity and Cognitive Health) study at Massey University (MU), Auckland, New Zealand. The REACH study aimed to identify the dietary patterns of independently living older adults 65 -74 years old and their associations with cognitive function and metabolic health (Mumme *et al*., 2019). The FFQ used as part of the REACH study was designed to assess nutrient, food groups, and dietary patterns in older adults. The 109-item self-administered FFQ was validated against a four-day food record (4DFR), and reproducibility of the FFQ was obtained by a repeated administration of a second FFQ four weeks later. Ethical approval for the REACH study was obtained from the Massey University Human Ethics Committee Southern A, Application 17/69. Written informed consent was obtained from all participants.

Participants and recruitment

Participants were males and females aged 65 to 74 years, living independently (not requiring assistance with daily activities or 24/7 care) and proficient in English. Participants were excluded if they had had a previous diagnosis of dementia, were taking medication which may affect cognitive function; or if they had or previously had had health conditions that may influence cognitive function, including stroke, traumatic head or brain injury, and neurological or psychiatric conditions. Participants were recruited through social media, posters in public areas, through radio stations, retirement villages and other aged care facilities, and by word of mouth. Participants were screened based on the eligibility criteria through telephone or email. Recommendations for the validation and reproducibility of an FFQ study suggests a sample size of at least 100 participants (Cade *et al*., 2002). Recruitment and data collection occurred between March 2018 and May 2019. Figure 3.1 shows the flow of participants through the current study. Participants completing the 4DFR were a convenience sub-sample of participants taking part in the REACH study.

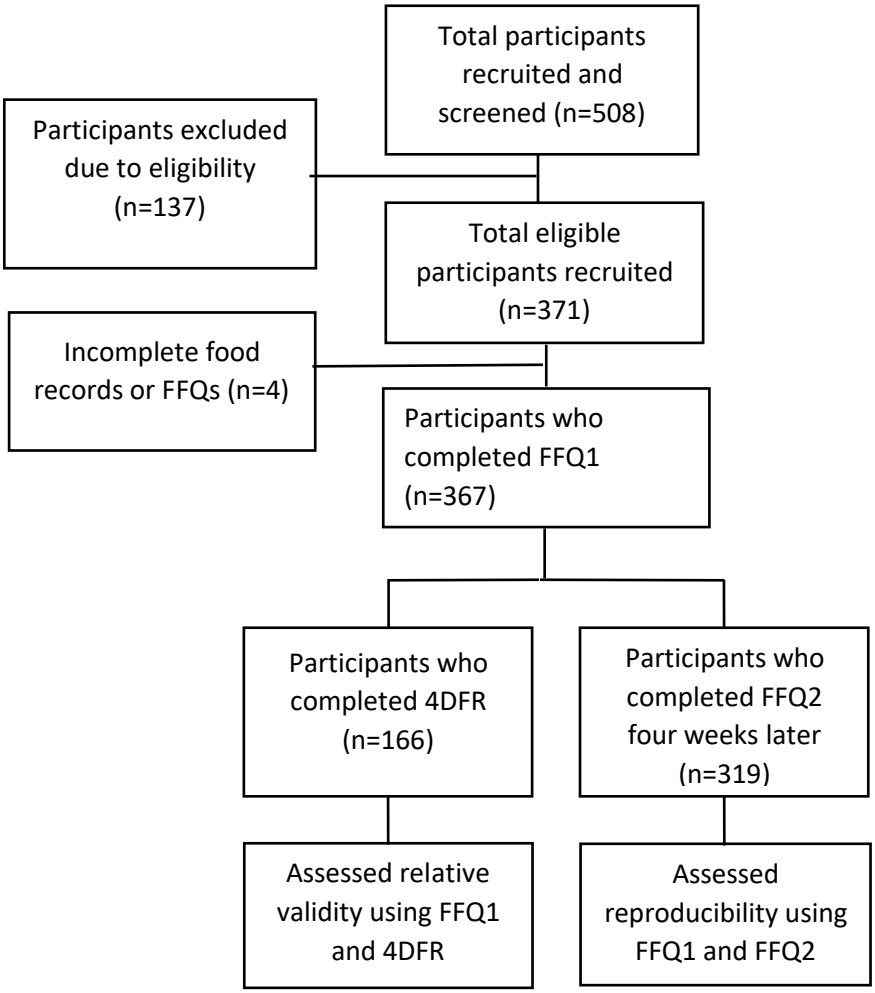


Figure 3.1 Flow chart of the participants in the FFQ validation and reproducibility study. Abbreviations: FFQ1, first food frequency questionnaire; FFQ2, re-administered food frequency questionnaire four weeks later; 4DFR, four-day food record.

Development of the FFQ

The semi-quantitative FFQ was derived from a validated New Zealand FFQ designed to measure iron related dietary patterns in young women (Beck *et al*., 2012). Changes were made including the addition of serving sizes and food items that were not included in the original validation study. This included food items that had not been included originally because they were not typically related to iron nutrition (for example, confectionary). Food groups were combined to shorten the original FFQ from 144 to 109 food groups/items. The FFQ was further cross-checked with the New Zealand Women's Food Frequency Questionnaire to ensure all relevant food groups were covered (Beck *et al*., 2018; Mumme *et*

al., 2019). The final FFQ consisted questions of ten frequency response options from "I never eat this food" to "six or more times per day". Three example questions were provided at the beginning of the FFQ to demonstrate how the FFQ should be completed. The FFQ was pilot tested on ten individuals in the study age range for understanding and readability. The FFQ was administered online using SurveyMonkey.

Data collection

During an appointment at MU, demographic information (age, gender, ethnicity, education levels) and anthropometric measurements were gathered. Standardised instructions were provided to assist participants in completing the questionnaires. Weight and height were measured once using the Wedderburn scale (Sauter) and stadiometer (Holtain) respectively, by trained researchers using a standardised protocol (Stewart *et al*., 2011).

The first self-administered online FFQ (FFQ1) was conducted during this appointment. Standardised instructions were provided and a researcher was available at all times during completion of the FFQ to answer any questions. At this appointment, participants were asked to complete a four-day food record at home. Participants were advised to record their usual diet over four consecutive days and include at least one weekend day. The specific days to be recorded were allocated by the researcher to ensure seven days of the week were recorded evenly across all participants. An instruction video was shown to participants describing how to complete the four-day food record including instructions on how to describe foods (e.g. type, brand, cooking methods) and instructions for estimating food quantities. Supplementary pictures of food portions on a standard size plate were provided (Nelson *et al*., 1997) to assist with estimating food quantities. Recipes used in home-cooked items were requested to be sent back via a pre-paid envelope with the food record upon completion. Where missing or incorrect information was suspected in the food record, participants were contacted by telephone or email for further investigation.

The FFQ was re-administered four weeks later (FFQ2) following the participant's first appointment via an online link. Participants who completed the FFQ at baseline and the 4DFR were included for the validation analysis, and participants who completed the online FFQ twice were included for analysis of reproducibly.

Data entry and management

The food records were entered into FoodWorks (Xyris Software, Australia Pty Ltd) by trained researchers using a food assumption list to ensure quality and consistency (See appendix C; Table 5.1). FoodWorks was used to summarise the mean daily intakes of total energy, macro-and micronutrients. The nutrient list for analysis included total energy, protein, carbohydrate, sugar, dietary fibre, alcohol, total fat, saturated fat, monounsaturated fat, polyunsaturated fat, cholesterol, thiamine, riboflavin, niacin, vitamins A, B6, folate, B12, C, E, beta-carotene, calcium, iron, iodine, magnesium, phosphorus, selenium, potassium, and zinc.

Foods were primarily selected from the New Zealand FOODFiles 2016 (NZ Plant and Food Research, 2019) and the Australia food database (AusFoods 2017 or AusBrands 2017) as a secondary option so that selected food items matched the food record as closely as possible. The NZ FOODFiles database was used to map the FFQ food items. When a single food item was unavailable, a new food composite was created manually using the existing food items from the NZ FOODFiles or generic food database to match the FFQ. These decisions were made in collaboration with three members of the research team (Appendix D; Table 5.2).

An energy cut-off point was applied to assess under-or over-reported energy intakes; the general established range is 2092-14644 kJ (500-3500 kcal) for women and 3347-16736 kJ (800-4000 kcal) for men (Rhee *et al*., 2015; Banna *et al*., 2017). All participants fell within these ranges therefore none were excluded from the analysis.

Statistical analysis

All statistical analyses were conducted with the Statistical Package for the Social Sciences (SPSS) software version 25 (IBM SPSS, Inc., Chicago, IL, USA). Firstly, data was checked for normality of distribution visually using Q-Q plots, histograms, and Kolmogorov-Smirnov and Shapiro-Wilk tests. Normally distributed data are reported as means and standard deviations (SD).

To assess the relative validity of energy and nutrient intakes from the FFQ against those from the 4DFR, a range of statistical methods were conducted. Pearson's or Spearman's correlation coefficients were used to compare energy and nutrient intakes from the FFQ1 with the food record, with the magnitude of the correlation (0 to +1) indicating the strength of

the relationship. Depending on normality, the paired t-test or Wilcoxon signed-ranks was used to compare the mean differences between the FFQ and 4DFR. Effect size was calculated when the test was significant. Cross-classification was used to categorise energy and nutrient intakes into tertiles from the FFQs and food record (Cade *et al*., 2002). It is recommended that at least 50% of participants should be correctly classified and less than 10% of participants grossly misclassified into the opposite tertiles for each nutrient (Masson *et al*., 2003). For further level of agreement, the weighted kappa statistic was used alongside cross-classification. The weighted kappa statistic was calculated based on the observed and expected percentage of agreement from the cross-classification table. Values of kappa over 0.80 indicate very good agreement, between 0.61 and 0.80 good agreement, 0.41–0.60 moderate agreement, 0.21–0.40 fair agreement, and 0.20 poor agreement (Masson *et al*., 2003). The Bland-Altman scatterplots were used for visual investigation of level of agreement with the difference between the two measurements for each nutrient plotted on the vertical axis and the average of the two measurements on the horizontal axis. Limits of agreement (LOA = mean difference ± 2 standard deviations) was calculated (Bland and Altman, 1986). Finally, the linear regression model was used to determine the degree of dependence of the predicting variable, in which the difference in nutrient intake was the dependent variable and mean nutrient intake was the independent variable. The same statistical methods used to assess validity were also used to assess reproducibility. For all statistical tests, a *p*-value of <0.05 was considered as statistically significant.

3.4 Results

3.4.1 Participant characteristics

A total of 367 participants completed FFQ1. An additional 319 participants completed FFQ2 four weeks later. The four-day food record (4DFR) was completed by 166 participants. The majority of participants were Europeans (94.6%). The mean ± SD age of older adults was 69.7 ± 2.6. Nearly two-thirds were female (62.7%), with a mean body mass index (BMI) of 26.1 ± 4.4 kg/m^2 (Ministry of Health, 2018). There was no significant difference in demographic characteristics between participants who completed the 4DFR and participants who did not (*p*-value > 0.05).

Table 3.1 Characteristics and demographics of the study participants (n=319)

Characteristics	Mean ± SD or n (%)
Age (y)	69.7 ± 2.6
Gender	
Female	200 (62.7)
Male	117 (36.7)
Gender diverse	2 (0.6)
Ethnicity	
European	302 (94.6)
Māori and Pacific Islanders	8 (2.5)
Asian	9 (2.8)
Education status	
No qualification	5 (1.6)
Secondary	68 (21.3)
Post-secondary	126 (39.5)
University	120 (37.6)
Height (cm)	167.6 ± 9.3
Weight (kg)	73.7 ± 15.1
BMI (kg/m^2)	26.1 ± 4.4
Underweight BMI: <18.5 kg/m^2	3 (0.9)
Normal BMI: 18.5-24.9 kg/m^2	133 (41.7)
Overweight BMI: 25-29.9 kg/m^2	137 (43.0)
Obese BMI: ≥30 kg/m^2	46 (14.4)

Note: Table include participants who completed FFQ1 and FFQ2; European, the total number of New Zealand European and other European from other countries. Abbreviations: BMI, Body Mass Index.

3.4.2 Relative validity of the FFQ

3.4.2.1 Mean comparisons and correlation coefficients

Correlations for mean energy and nutrient intakes ranged from 0.06 (selenium) to 0.77 (Alcohol), with a mean of 0.32. After energy adjustments, most correlation coefficients improved moderately, and ranged from 0.12 (folate) to 0.76 (alcohol) with most correlations falling between 0.30 and 0.60. The energy adjusted correlation coefficients were statistically significant for mean energy and all nutrients, except for folate and selenium (p-value<0.05).

Table 3.2 Mean daily nutrient intake from FFQ1 and 4DFR and correlation coefficients (n=166)

Nutrient	FFQ1 mean ± SD	4DFR mean ± SD	Mean difference ± SD	Percentage difference (%)	P-value	Effect size	Correlation coefficients		Correlation significance (*p*-value)	
							Raw	Adjusted	Raw	Adjusted
Energy	7613.5 ± 2195.7	8117.2 ± 1765.5	-503.7 ± 2328.5	-6.21	0.006	0.21	0.33	-	< 0.001	-
Protein	80.6 ± 23.9	83.6 ± 18.8	-2.7 ± 23.8	-3.23	0.143	-	0.40	0.39	< 0.001	< 0.001
Carbohydrate	181.1 ± 61.0	192.2 ± 55.0	-11.1 ± 58.8	-5.78	0.016	0.19	0.50	0.59	< 0.001	< 0.001
Sugars	115.7 ± 43.4	89.1 ± 33.0	26.5 ± 42.5	29.7	< 0.001	0.53	0.41	0.42	< 0.001	< 0.001
Dietary fibre	25.9 ± 9.2	28.6 ± 8.7	-2.7 ± 9.4	-9.44	< 0.001	0.27	0.45	0.53	< 0.001	< 0.001
Alcohol*	6.9 ± 8.7	9.3 ± 11.4	-2.4 ± 8.7	-25.8	0.001	0.26	0.77	0.76	<0.001	< 0.001
Total fat	74.6 ± 25.6	79.3 ± 24.5	-4.7 ± 31.3	-5.93	0.056	-	0.22	0.44	0.004	< 0.001
SAFA	32.5 ± 13.5	29.3 ± 10.9	3.2 ± 15.2	10.9	0.008	0.21	0.23	0.33	0.003	< 0.001
MUFA	23.4 ± 8.3	28.5 ± 10.1	-5.1 ± 11.2	-17.9	< 0.001	0.41	0.29	0.44	< 0.001	< 0.001
PUFA	10.2 ± 4.3	12.9 ± 5.7	-2.7 ± 6.0	-20.9	< 0.001	0.41	0.30	0.54	< 0.001	< 0.001
Cholesterol	283.8 ± 115.4	291.2 ± 114.3	-7.4 ± 124.2	-2.54	0.444	-	0.42	0.59	< 0.001	< 0.001
Thiamine	1.0 ± 0.4	1.6 ± 0.9	-0.5 ± 0.8	-31.3	< 0.001	0.52	0.32	0.30	< 0.001	< 0.001
Riboflavin	3.1 ± 1.4	2.2 ± 0.8	0.9 ± 1.4	29.0	< 0.001	0.56	0.29	0.23	< 0.001	0.003
Niacin equiv.	38.2 ± 11.2	34.4 ± 9.4	3.9 ± 13.3	11.3	< 0.001	0.28	0.17	0.16	0.030	0.039
Vitamin B6	3.0 ± 0.9	2.3 ± 0.9	0.7 ± 1.1	30.4	< 0.001	0.56	0.31	0.20	< 0.001	0.011
Folate	362.2 ± 117.7	440.5 ± 166.1	-78.3 ± 189.3	-17.8	< 0.001	0.38	0.14	0.12	0.067	0.140
Vitamin B12	5.2 ± 3.0	4.2 ± 3.3	1.0 ± 3.9	23.8	0.002	0.24	0.24	0.25	0.002	0.001
β-carotene	4340.7 ± 2019.6	4048.7 ± 2996.8	291.8 ± 3117.8	7.21	0.229	-	0.28	0.33	< 0.001	< 0.001
Vitamin A	1437.5 ± 899.7	1195.8 ± 1231.2	241.8 ± 1401.5	20.2	0.028	0.17	0.16	0.23	0.036	0.003
Vitamin C	133.3 ± 74.1	124.3 ± 72.3	9.0 ± 84.2	7.24	0.171	-	0.34	0.38	< 0.001	< 0.001
Vitamin E	10.1 ± 3.8	11.4 ± 5.0	-1.3 ± 5.3	-11.4	0.002	0.24	0.31	0.50	< 0.001	< 0.001
Calcium	1249.2 ± 576.4	939.7 ± 321.1	309.6 ± 527.0	33.0	< 0.001	0.51	0.43	0.42	< 0.001	< 0.001
Iron	10.0 ± 3.0	12.3 ± 3.6	-2.3 ± 3.9	-18.7	< 0.001	0.51	0.31	0.19	< 0.001	0.016
Iodine	89.2 ± 37.7	108.4 ± 41.6	-19.2 ± 49.8	-17.7	< 0.001	0.36	0.21	0.27	0.006	< 0.001
Potassium	4005.6 ± 1138.9	3555.0 ± 912.8	450.6 ± 1204.0	12.7	< 0.001	0.35	0.33	0.14	< 0.001	0.076
Magnesium	344.6 ± 97.9	383.2 ± 108.4	-38.5 ± 111.5	-10.1	< 0.001	0.33	0.42	0.48	< 0.001	< 0.001

Nutrient	FFQ1 mean ± SD	4DFR mean ± SD	Mean difference ± SD	Percentage difference (%)	P-value	Effect size	Correlation coefficient		Correlation significance (*p*-value)	
							Raw	Adjusted	Raw	Adjusted
Phosphorus	1508.7 ± 510.4	1525.3 ± 366.2	-16.6 ± 508.3	-1.09	0.675	-	0.36	0.30	< 0.001	< 0.001
Selenium	46.3 ± 16.5	80.0 ± 45.0	-33.7 ± 47.1	-42.1	< 0.001	0.58	0.06	0.05	0.483	0.523
Zinc	10.5 ± 3.3	10.2 ± 3.0	0.3 ± 3.4	2.94	0.217	-	0.40	0.28	< 0.001	< 0.001

Effect size calculated for significant paired t-test and Wilcoxon's test results. *Spearman's correlation coefficients and Wilcoxon rank test used for non-normally distributed data (alcohol). Significant results, *p*-value <0.05. Abbreviations: Mean ± SD, mean and standard deviation; FFQ1, First administered food frequency questionnaire; 4DFR, Four-day food records; SAFA, Saturated fat; PUFA, Polyunsaturated fatty acids; MUFA, Monounsaturated fatty acids; Niacin equiv., Niacin equivalents total, the sum of the percentage of niacin, preformed and niacin equivalent from tryptophan.

3.4.2.2 Cross-classification and weighted kappa statistics

The participants who were correctly classified into the same tertiles ranged from 37% (total fat) to 70% (alcohol), with a mean of 44%. Twenty nutrients had correct classification between 40 to 50% of participants. Three nutrients had at least 50% of participants correctly classified into the same tertiles; alcohol (67%), β-carotene (56%), and phosphorus (55%) (Table 3.3). Most nutrients were grossly misclassified above 10% except for carbohydrate, alcohol, and vitamin C. After energy adjustments, correct classification at least 50% was observed for eight nutrients, and less than 10% of participants grossly misclassified was observed for seven nutrients. However, β-carotene and phosphorus no longer had at least 50% of participants correctly classified into the same tertiles as shown in Table 3.3.

Weighted kappa values showed poor agreement (κ <0.20) for mean energy and 13 nutrients, fair agreement (κ = 0.21–0.40) for 14 nutrients, and good agreement (κ = 0.61-0.80) for alcohol. After energy adjustments, poor agreement (κ <0.20) was observed in eight nutrients, fair agreement (κ = 0.41-0.60) in 19 nutrients, and good agreement (unchanged) for alcohol intake (Table 3.3).

Table 3.3 Cross-classification and weighted kappa for nutrient intakes compared between FFQ1 and 4DFR for validity (n=166)

Nutrient	Correctly classified into same tertiles (%)		Grossly misclassified into opposite tertiles (%)		Weighted kappa statistics (κ)	
	Raw	Adjusted	Raw	Adjusted	Raw	Adjusted
Energy	39.8	-	13.3	-	0.175	-
Protein	49.4	50.1	13.3	12.1	0.283	0.310
Carbohydrate	42.8	53.0	9.04	8.43	0.256	0.378
Sugars	45.8	48.2	10.8	12.1	0.269	0.283
Dietary fibre	44.6	53.0	12.0	8.43	0.242	0.378
Alcohol	69.9	68.1	2.41	3.01	0.635	0.608
Total fat	36.8	44.6	15.1	15.7	0.120	0.202
SAFA	39.8	48.0	16.3	15.1	0.141	0.245
MUFA	38.0	50.0	15.1	12.7	0.134	0.296
PUFA	45.8	52.4	14.5	6.63	0.229	0.391
Cholesterol	44.0	54.8	17.5	10.2	0.175	0.378
Thiamine	46.4	45.8	12.7	10.8	0.256	0.269
Riboflavin	41.6	43.4	16.3	16.9	0.161	0.175
Niacin equiv.	42.8	44.6	15.1	15.7	0.188	0.202
Vitamin B6	38.0	38.0	17.5	18.7	0.107	0.093
Folate	40.0	33.1	19.3	18.7	0.107	0.039
Vitamin B12	43.4	44.0	13.3	12.7	0.215	0.229
β-carotene	56.4	48.2	15.1	10.8	0.229	0.296
Vitamin A	40.0	43.4	18.1	13.3	0.120	0.215
Vitamin C	44.6	49.4	9.64	8.43	0.269	0.337
Vitamin E	43.4	47.0	15.7	6.03	0.188	0.337
Calcium	44.6	41.6	16.7	10.2	0.202	0.229
Iron	44.6	39.8	14.5	14.5	0.215	0.161
Iodine	43.4	38.0	16.9	15.0	0.175	0.134
Potassium	40.4	44.0	13.9	17.5	0.175	0.175
Magnesium	49.4	52.4	10.8	9.04	0.310	0.364
Phosphorus	54.8	41.0	14.5	12.1	0.229	0.202
Selenium	37.9	43.4	21.1	16.9	0.066	0.175
Zinc	47.0	43.4	10.8	20.5	0.283	0.134
Mean	44.7	46.5	14.2	12.6	0.212	0.258

Adjusted, energy adjusted nutrient intakes. Abbreviations: SAFA, Saturated fatty acid; MUFA, Monounsaturated fatty acid; PUFA, Polyunsaturated fatty acid; Niacin equiv., Niacin equivalents total, is the sum of the percentage of niacin, preformed and niacin equivalent from tryptophan.

3.4.2.3 Bland-Altman analysis and linear regression between FFQ1 and 4DFR

Bland-Altman analysis was performed to measure the level of agreement between FFQ1 and 4DFR, as well as to identify outliers. The Bland-Altman plots demonstrate the width of the limits of agreement and the consistency of variance across the mean intake. An example of the Bland-Altman plot for calcium intake is provided in Figure 3.2, the difference in unadjusted calcium intake spreads further across the mean difference (middle line) as the mean calcium intake increases. The LOA was smaller in energy adjusted calcium intake than unadjusted calcium (Supplementary Table 1).

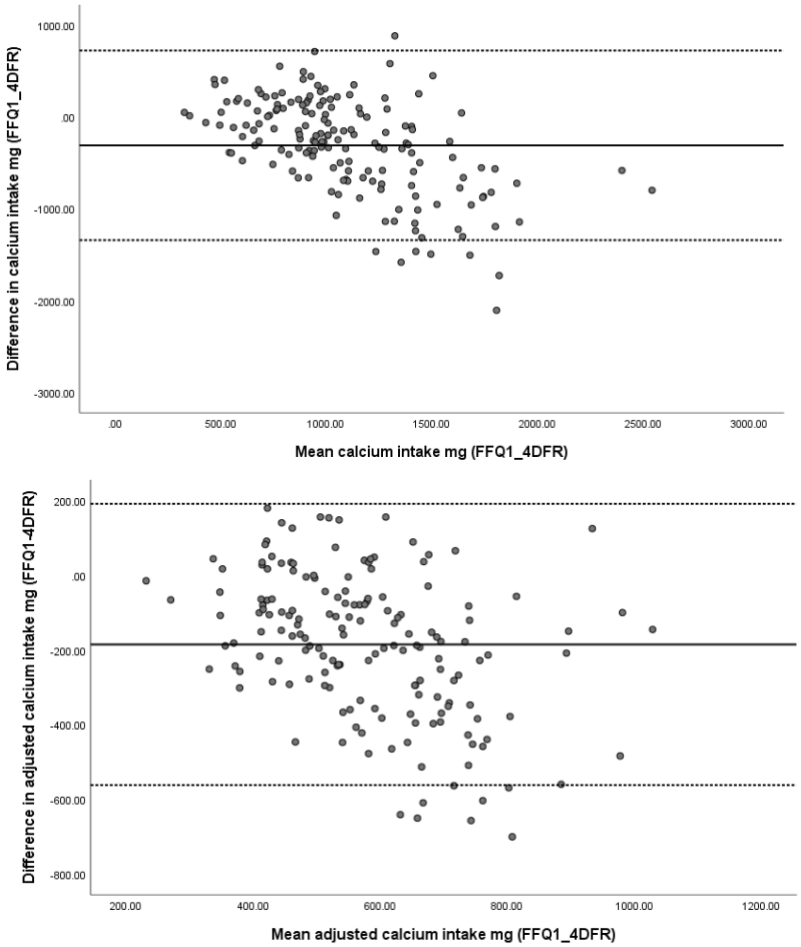


Figure 3.2 An example of Bland-Altman plot of agreement for calcium intake (unadjusted and energy adjusted intake) between FFQ1 and 4DFR. The middle line represents the mean difference between two dietary assessment methods; the dotted lines represent the limits of agreement (LOA = mean difference ± 1.96 standard deviation).

The mean unstandardized coefficients (β) was near zero for all nutrient intakes ranging from -0.8 (riboflavin and vitamin E) to 1.5 (selenium) with a mean of 0.07 (Supplementary Table

1). The slope of the bias was statistically significant (*p*-value < 0.05) for the majority of nutrients (n = 20), whereas, carbohydrate, alcohol, total fat, cholesterol, vitamin B6 and C, iodine, magnesium, and zinc showed non-significant results. After energy adjustment, non-significant results were observed for 13 nutrients indicating the difference between the two methods was not significantly dependent on the mean intake (Supplementary Table 1).

3.4.3 Reproducibility of the FFQ

3.4.3.1 Mean comparison and correlation coefficients

The mean energy and nutrient intakes from the baseline (FFQ1) and four weeks later (FFQ2) were compared against each other, as shown in table 3.4. Mean intake of energy and the majority of nutrients from FFQ1 were higher than FFQ2. Both FFQs had similar mean intakes, all nutrients had mean percentage differences less than 10% except for vitamin C (10.5%). The correlations for nutrient intakes ranged from 0.28 (Vitamin A) to 0.90 (alcohol), with a mean correlation of 0.63 (*p*-value <0.05 for all nutrients). Correlations for energy adjusted nutrients ranged from 0.30 (vitamin A) to 0.91 (alcohol) with a mean of 0.66 (significant, *p*-value <0.05 for all nutrients). Correlation coefficients for most nutrients (n = 24) fell between 0.60 and 0.79. Most correlations improved moderately after energy adjustments, if not remained the same except for thiamine, vitamin B6, iron, and iodine (Table 3.4).

Table 3.4 Mean daily nutrient intake from FFQ1 and FFQ2 and correlation coefficients (n=319)

Nutrient	FFQ1 mean ± SD	FFQ2 mean ± SD	Mean difference ± SD	Percentage difference (%)	P-value	Effect size	Correlation coefficients		Correlation significance (*p*-value)	
							Raw	Adjusted	Raw	Adjusted
Energy	7609.7 ± 2316.3	7201.4 ± 2201.1	408.3 ± 1906.7	5.67	< 0.001	0.21	0.65	-	< 0.001	-
Protein	80.7 ± 25.8	76.4 ± 23.6	4.3 ± 22.7	5.63	0.001	0.19	0.58	0.63	< 0.001	< 0.001
Carbohydrate	181.2 ± 40.8	169.0 ± 59.6	12.2 ±50.7	7.22	< 0.001	0.23	0.68	0.77	< 0.001	< 0.001
Sugars	115.0 ± 46.3	106.3 ± 40.8	8.3 ±37.9	7.81	< 0.001	0.22	0.63	0.68	< 0.001	< 0.001
Dietary fibre	26.3 ± 10.2	24.3 ± 10.2	2.0 ± 7.8	8.23	< 0.001	0.25	0.71	0.76	< 0.001	< 0.001
Alcohol*	7.68 ± 9.17	8.30 ± 12.0	0.62 ± 7.8	7.47	0.801	-	0.90	0.91	<0.001	< 0.001
Total fat	73.9 ± 25.1	70.4 ± 25.1	3.5 ± 20.5	4.97	0.002	0.17	0.67	0.75	< 0.001	< 0.001
SAFA	31.9 ± 12.8	30.4 ± 12.7	1.5 ± 10.1	4.93	0.008	0.15	0.68	0.72	< 0.001	< 0.001
MUFA	23.4 ± 8.1	22.3 ± 8.0	1.1 ± 7.0	4.93	0.006	0.15	0.62	0.65	< 0.001	< 0.001
PUFA	10.2 ± 4.1	9.8 ± 4.4	0.5 ± 3.3	5.10	0.01	0.14	0.70	0.72	< 0.001	< 0.001
Cholesterol	287.8 ± 146.2	278.0 ± 125.0	9.8 ± 128.2	3.54	0.172	0.08	0.56	0.68	< 0.001	< 0.001
Thiamine	1.0 ± 0.4	1.0 ± 0.4	0.07 ± 0.3	7.00	< 0.001	0.21	0.68	0.61	< 0.001	< 0.001
Riboflavin	3.0 ± 1.4	2.8 ± 1.4	0.2 ± 1.1	7.14	< 0.001	0.20	0.65	0.68	< 0.001	< 0.001
Niacin equiv.	38.3 ± 12.0	36.5 ± 11.7	1.8 ± 9.7	4.93	0.001	0.19	0.67	0.71	< 0.001	< 0.001
Vitamin B6	3.0 ± 1.0	2.8 ± 1.0	0.2 ± 0.7	7.14	< 0.001	0.21	0.73	0.72	< 0.001	< 0.001
Folate	366.4 ± 137.5	340.0 ± 135.6	26.4 ± 127.5	7.76	< 0.001	0.20	0.56	0.60	< 0.001	< 0.001
Vitamin B12	5.2 ± 4.2	4.8 ± 3.0	0.4 ± 4.1	8.33	0.078	-	0.40	0.40	< 0.001	< 0.001
β-carotene	4539.2 ± 2239.5	4248.6 ± 2891.3	290.6 ± 2447.7	6.84	0.035	0.12	0.57	0.61	< 0.001	< 0.001
Vitamin A	1469.0 ± 1336.7	1339.0 ± 928.7	130.0 ± 1402.1	9.71	0.099	-	0.28	0.30	< 0.001	< 0.001
Vitamin C	137.1 ±79.9	124.1 ± 73.7	13.0 ± 69.5	10.5	0.001	0.18	0.59	0.64	< 0.001	< 0.001
Vitamin E	10.3 ± 4.0	9.6 ± 3.8	0.7 ± 3.0	7.29	< 0.001	0.22	0.69	0.76	< 0.001	< 0.001
Calcium	1196.7 ± 564.1	1109.3 ± 512.8	87.3 ±455.7	7.87	0.001	0.19	0.67	0.68	< 0.001	< 0.001
Iron	10.1 ±3.4	9.5 ± 3.5	0.6 ± 3.1	6.32	0.001	0.18	0.61	0.60	< 0.001	< 0.001
Iodine	87.6 ± 38.8	82.7 ± 35.6	5.0 ± 32.7	6.05	0.007	0.15	0.62	0.59	< 0.001	< 0.001
Potassium	4000.7 ± 1243.4	3710.7 ± 1160.6	289.9 ± 1048.4	7.81	< 0.001	0.27	0.62	0.63	< 0.001	< 0.001
Magnesium	341.8 ± 105.0	319.7 ± 99.4	22.1 ± 84.0	6.91	< 0.001	0.25	0.66	0.71	< 0.001	< 0.001
Phosphorus	1482.3 ± 520.8	1385.6 ± 468.1	96.7 ± 149.2	6.98	< 0.001	0.23	0.65	0.68	< 0.001	< 0.001
Selenium	47.3 ± 19.6	46.1 ± 21.4	1.2 ± 20.2	2.60	0.292	-	0.52	0.63	< 0.001	< 0.001

Nutrient	FFQ1 mean ± SD	FFQ2 mean ± SD	Mean difference ± SD	Percentage difference (%)	P-value	Effect size	Correlation coefficients		Correlation significance (*p*-value)	
							Raw	Adjusted	Raw	Adjusted
Zinc	10.5 ± 3.5	9.9 ± 3.3	0.6 ± 3.2	6.06	0.001	0.18	0.57	0.60	< 0.001	< 0.001

Effect size calculated for significant paired t-test and Wilcoxon's test results. *Spearman's correlation coefficients and Wilcoxon rank test used for non-normally distributed data (alcohol). Significant results, *p*-value <0.05. Abbreviations: Mean ± SD, mean and standard deviation; FFQ1, First administered food frequency questionnaire; 4DFR, Four-day food records; SAFA, Saturated fatty acid; PUFA, Polyunsaturated fatty acid; MUFA, Monounsaturated fatty acid; Niacin equiv., Niacin equivalents total, the sum of the percentage of niacin, preformed and niacin equivalent from tryptophan.

3.4.3.2 Cross-classification and weighted kappa statistics

At least 50% of participants were correctly classified into the same tertiles for mean energy and all nutrients, ranging from 53% (selenium) to 81% (alcohol), with the mean of 61.5%. Less than 10% of participants were grossly misclassified into the opposite tertiles for energy and all nutrients, ranging from 1.3% (Alcohol) to 6.6% (vitamin A). Moderate agreement (weighted kappa value 0.41 – 0.60) between FFQ1 and FFQ2 was observed for energy and 28 nutrients, ranging from 0.40 (selenium) to 0.77 (alcohol), with a mean of 0.51 (Table 3.5). Alcohol had the highest weight kappa value, followed by vitamin B6 (0.58), niacin (0.55) and phosphorus (0.55). There were no significant changes in cross-classification and weighted kappa values after energy adjustment was performed (Table 3.5).

Table 3.5 Cross-classification and weighted kappa for nutrient intakes compared between FFQ1 and FFQ2 (n=319)

Nutrient	Correctly classified into same tertiles (%)		Grossly misclassified into opposite tertiles (%)		Weighted kappa statistics (κ)	
	Raw	Adjusted	Raw	Adjusted	Raw	Adjusted
Energy	58.3	-	3.5	-	0.493	-
Protein	61.1	55.2	5.64	7.21	0.500	0.415
Carbohydrate	63.0	65.2	3.76	2.19	0.542	0.584
Sugars	61.8	60.5	3.13	6.90	0.535	0.479
Dietary fibre	56.7	64.6	3.76	2.82	0.471	0.570
Alcohol	81.2	78.1	1.25	0.63	0.774	0.746
Total fat	62.4	60.1	4.39	5.02	0.528	0.500
SAFA	63.0	61.4	4.39	4.08	0.535	0.521
MUFA	59.3	58.6	4.39	6.27	0.493	0.464
PUFA	61.4	65.2	5.96	3.45	0.500	0.570
Cholesterol	58.3	60.0	4.70	6.27	0.479	0.457
Thiamine	60.0	58.0	5.02	3.76	0.493	0.486
Riboflavin	63.0	60.0	4.39	5.96	0.535	0.479
Niacin equiv.	64.9	61.4	5.02	2.19	0.549	0.542
Vitamin B6	65.5	62.1	3.13	2.82	0.577	0.542
Folate	56.7	56.7	4.39	5.02	0.464	0.457
Vitamin B12	63.3	62.4	4.70	3.76	0.535	0.535
β-carotene	58.9	61.1	3.45	3.76	0.500	0.521
Vitamin A	59.6	53.9	6.58	7.84	0.471	0.394
Vitamin C	64.0	60.2	4.70	2.82	0.542	0.521
Vitamin E	61.1	62.1	4.39	5.33	0.479	0.514
Calcium	64.0	58.3	5.33	5.33	0.535	0.471
Iron	58.6	57.7	6.27	5.33	0.464	0.464
Iodine	59.6	52.7	4.08	7.84	0.500	0.380
Potassium	59.9	55.2	4.39	4.08	0.500	0.450
Magnesium	61.1	56.1	4.39	5.02	0.514	0.450
Phosphorus	64.0	60.0	4.08	7.84	0.549	0.457
Selenium	52.7	57.1	5.96	5.96	0.401	0.413
Zinc	56.4	58.3	4.70	5.33	0.457	0.471
Mean	61.4	60.1	4.48	4.82	0.514	0.495

Adjusted, energy adjusted nutrient intakes. Abbreviations: SAFA, Saturated fatty acid; MUFA, Monounsaturated fatty acid; PUFA, Polyunsaturated fatty acid; Niacin equiv., Niacin equivalents total, is the sum of the percentage of niacin, preformed and niacin equivalent from tryptophan.

3.4.3.3 Bland-Altman analysis and linear regression for FFQ1 and FFQ2

The Bland-Altman plots were used to demonstrate the trend and the extent of the bias for reproducibility. An example is shown in Figure 3.3, the variance of difference in calcium intake was less consistent across the unadjusted calcium intake compared to the energy adjusted calcium intake.

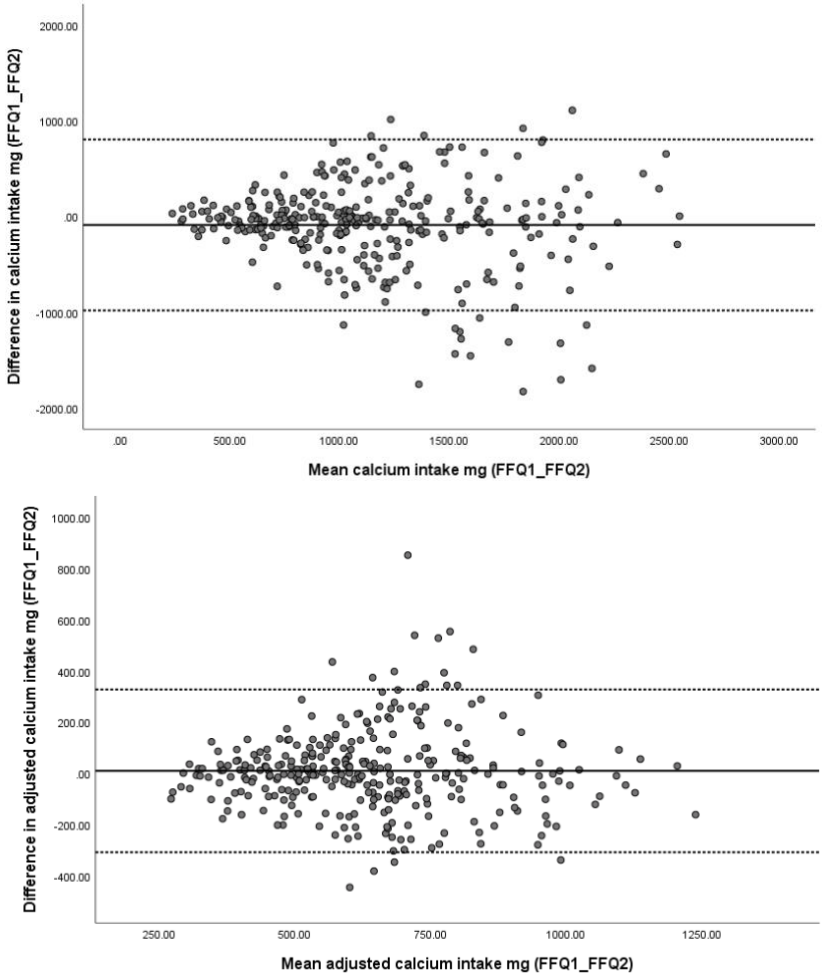


Figure 3.3 An example of Bland-Altman plot of agreement for calcium intake (unadjusted and energy adjusted intake) between FFQ1 and FFQ2. The middle line represents the mean difference between two dietary assessment methods; the dotted lines represent the limits of agreement (LOA = mean difference ± 1.96 standard deviation).

The unstandardized coefficients for the mean energy and all nutrients were near zero, with a mean of -0.05. Linear regression (slope of bias) for 11 nutrients was statistically significant, as shown in Supplementary Table 2. Carbohydrate, sugar, alcohol, cholesterol, thiamine, riboflavin, β-carotene, vitamin A, B12, calcium, and phosphorus demonstrated significant

results, indicating the difference in intake was significantly dependent on the mean intake (*p*-value <0.05). The agreement between FFQ1 and FFQ2 was relatively consistent across the mean intake for energy and the remaining 17 nutrients based on their significance. The figures remained unchanged or had similar results after the energy adjustments (Supplementary Table 2).

3.5 Discussion

To the best of our knowledge, the current study is the first to explore the relative validity and reproducibility of an FFQ aiming to measure multiple nutrient intakes in older New Zealand adults in 28 years. The food frequency questionnaire (FFQ) was compared against the four-day food record (4DFR) to assess relative validity, and an FFQ was re-administered four weeks later to assess reproducibility. Overall, the FFQ demonstrated fair relative validity for ranking nutrient intakes in older adults. The FFQ showed good reproducibility of a dietary assessment tool.

3.5.1 Validity of the FFQ

For validity, correlation coefficients for unadjusted energy nutrients ranged from 0.06 (selenium) to 0.77 (alcohol), with a mean of 0.32. The statistical results are similar to other validity studies of FFQ in New Zealand adults with unadjusted nutrient correlations ranging from 0.11-0.50 (Sam *et al*., 2014), 0.11-0.59 (Beck *et al*., 2018), 0.34-0.75 (Horwath, 1993), 0.36-0.84 (Metcalf *et al*., 1997), 0.21-0.65 (Sharpe *et al*., 1993). Results were similar to validity correlations for nutrients in populations of older age internationally; 0.11-0.76 (Boucher *et al*., 2006), 0.18-0.60 (Carithers *et al*., 2009), 0.09-0.78 (Smith *et al*., 1998), 0.31-0.67 (Morris *et al*., 2003), 0.01-0.40 (Watanabe *et al*., 2019), 0.38-0.55 (Malekahmadi *et al*., 2016). These validation studies in adults used similar methodologies and reference methods (Drewnowski and Evans, 2001; Cade *et al*., 2002). After energy adjustments, validity correlations between the FFQ and 4DFR improved moderately for most nutrients (n = 16).

Since correlation coefficients are unable to measure absolute agreement, other statistic methods should be used alongside correlations in validity studies (Cade *et al*., 2002). The FFQ over-estimated some nutrients but under-estimated other nutrients when compared with the 4DFR; the difference percentages ranged from -42.1% (selenium) to 33.0% (calcium), 19

nutrients (out of 29) had a mean difference less than 20%. The results were similar when compared with other validity studies who analysed similar nutrients in New Zealand adults; -16% to 64% (Beck *et al*., 2018), -16% to 70% (Sam *et al*., 2014). Similar results for the same nutrients were found in another FFQ validation study conducted in older New Zealanders with the percentage difference ranging from -31% to 19% in both genders (Horwath, 1993).

The majority of nutrients (n = 23) had at least 40% of participants correctly classified into the same tertiles; with three nutrients having at least 50% correct classification. The lowest percentage of correct classification was observed for total fat intake (36.8%). Gross misclassification ranged from 2.4% (alcohol) to 21.0% (selenium). After energy adjustment, at least 50% of participants were correctly classified for nine nutrients and less than 10% of participants grossly misclassified for seven nutrients. Ideally, correct classification should occur for at least 50% and gross misclassification for less than 10% of participants (Masson *et al*., 2003). However, the results exceeded another validation study that also used tertiles in young Samoan in New Zealand with cross-classification ranging from 29% (vitamin C) to 53% (sugar) (Bell *et al*., 1999). Most validation studies in older adults used quartiles (Carithers *et al*., 2009; Sam *et al*., 2014) or quintiles (Sharpe *et al*., 1993; Smith *et al*., 1998), therefore, comparison across studies is difficult. The weighted kappa was calculated to overcome agreement that may have occurred by chance in the cross-classification process (Masson *et al*., 2003). Weighted kappa values ranged from 0.07 to 0.64, with a mean of 0.30. These results are comparable in similar validation studies undertaken internationally; where weighted kappa values have ranged from 0.36 to 0.50 (Corrente *et al*., 2013) and from 0.14 to 0.37 (Gilsing *et al*., 2018) in older adults, and between 0.08 to 0.66 in adults (age 19-58 y) (Masson *et al*., 2003).

Based on the linear regression analysis, statistically non-significant results were observed for twelve nutrients after energy adjustments, indicating the difference in nutrient intakes between FFQ1 and the 4DFR were not significantly dependent on the mean intake (Supplementary Table 1). Bland-Altman plots demonstrated increased variance in nutrient intake between the FFQ and 4DFR as the mean intake increased, except for carbohydrate, total fat, alcohol, and five other nutrients which had relatively constant variance across the mean (Appendix F; Figure 5.1). After energy adjustment, the limits of agreement and its significance improved moderately compared to unadjusted nutrients (Bland and Altman, 1999), for example, the significance of linear regression in carbohydrate, alcohol, sugar, and saturated fat intakes was strengthened after energy adjustments (Supplementary Table 1).

Overall, the FFQ demonstrated reasonable relative validity when compared to the 4DFR. The lowest energy adjusted correlations were observed in folate, selenium, vitamin A, and niacin. These nutrients tend to be naturally rich in only a few food items. For example, high levels of vitamin A is found in kumara, carrots, and pumpkin which may result in fluctuations in nutrient intakes if high intakes of these foods are consumed at specific time points. Longer periods of time may be needed for accurate measurements of some nutrients such as vitamin A. Furthermore, participants are likely to mis-or under-estimate food intakes in self-administered dietary assessment methods including both the FFQ and food records. Another probable reason for poor correlations may be that participants from older age groups have difficulties estimating food intake, even with a supplementary book or other measurement aids, an accurate estimate of portion size may still be substandard in self-administered dietary assessments for older populations (Thompson and Byers, 1994). There is also the possibility that participants simply had significantly different dietary intakes from usual at the time of documenting the 4DFR or FFQ due to holiday periods or seasonality.

3.5.2 Reproducibility of nutrients from the FFQ

The mean difference between energy and nutrients from FFQ1 and FFQ2 were insignificant and ranged from 2.6 to 10.5%. Energy adjusted correlation coefficients between the FFQs ranged from 0.30 (vitamin A) to 0.91 (alcohol). Other reproducibility studies in New Zealand have reported similar correlations in adults ranging from 0.47-0.83 (Sam *et al*., 2014) to 0.41-0.88 (Metcalf *et al*., 1997) and in older adults internationally; 0.46-0.65 (Malekahmadi *et al*., 2016) and 0.61-0.80 (Smith *et al*., 1998). Cross-classification between FFQ1 and FFQ2 showed good agreements. As recommended by the literature (Masson *et al*., 2003), at least 50% of participants were correctly classified into the same tertiles for energy and all nutrients (n = 28) ranging from 53% (selenium) to 81% (alcohol). The percentage of participants grossly misclassified into opposite tertiles ranged from 1% to 6.6% for all nutrients. However, the number of segments used in cross-classification can affect the proportion of classification. For example, using tertiles instead of quintiles may increase the percentage of participants correctly classified and grossly misclassified (Willett, 2012). Therefore, it is difficult to compare studies using tertiles, quartiles and quintiles. The weighted kappa statistics demonstrated moderate to good agreement between the two FFQs ranging from 0.40 (selenium) to 0.77 (alcohol). The weighted kappa values were similar to studies in older

adults for reproducibility internationally; between 0.24-0.40 (Jia *et al*., 2009), and 0.46-0.86 (Smith *et al*., 1998).

Bland-Altman plots demonstrated moderate to good agreement between FFQ1 and FFQ2. As linear regression analysis in 19 nutrients (energy adjusted) demonstrated non-significant results, indicating the difference between FFQ1 and FFQ2 was not significantly dependent on the mean intake. In the current study, reproducibility showed moderate to strong agreement between FFQs. According to Bland and Altman (1999), correlations already exist between the same dietary assessment methods at different administration times, therefore, strong agreements for reproducibility of nutrients are usually expected (Bland and Altman, 1999). As suggested by Willet (2012), the ideal method to assess reproducibility is combining two re-administered FFQs (short and long time intervals) and compare them to the baseline FFQ (Willett, 2012). However, this is not always suitable for every research design. Furthermore, longer time interval (12 months) of re-administered FFQs may reduce the correlations unintentionally and render the true reproducibility of an FFQ (Block and Hartman, 1989). Another reason for strong reproducibility is that dietary intakes in older adults may have been more well established compared to younger populations due to habitual behaviours, this might explain good reproducibility of dietary intakes from the FFQ.

Energy adjustment is recommended to improve validity and reproducibility correlations. Energy adjustment ensures nutrient intake is independent of energy intake and reduces measurement error related to the reported energy intake (Cade *et al*., 2002). With the suggestion for stronger results, nutrient intake was adjusted for energy intake in the current study; the nutrient density model was applied in both validity and reproducibility analysis (Willett *et al*., 1997), and overall improved the agreement between dietary assessment methods.

Under-reporting in older adults is commonly seen in self-reported dietary assessments (Thompson and Byers, 1994; Willett, 2012). The simplest method to identify mis-reported energy intakes is to examine extreme intakes that are out of the proposed energy range; the energy cut-off applied for women is 2092-14644 kJ (500-3500 kcal), and 3347-16736 kJ (800-4000 kcal) for men (Rhee *et al*., 2015; Banna *et al*., 2017). Based on this cut-off, all reported energy intakes from the FFQs and food records were within the range in the current study. However, this crude method does not consider each individual profile and may not

identify all under-or over-reported energy intakes. Participants who completed the food records were not disqualified for data analysis, as exclusion of participants from the study population may increase the risk of altered results from selection bias. Under-reporting could also occur with the FFQ, therefore, it is reasonable to include all participants who completed both dietary assessment methods in the study.

3.5.3 Strengths and limitations in assessing validation and reproducibility

There were a number of strengths to the current validation study. Considering the number of challenges in assessing dietary intake and recruiting older adults, the current study was able to obtain a large sample size (n = 367) from a convenience subpopulation from the REACH study. A wide range of statistical methods were used to assess validity and reproducibility as recommended, including paired t-tests, correlation coefficients, cross-classification with weighted kappa statistics, Bland-Altman plots, and linear regression analysis. 28 nutrients were adjusted for energy to control for the confounding effects of energy intake; the FFQ showed moderate improvements in validity and reproducibility after energy adjustments (Willett, 2012; Cade *et al*., 2002).

There were also a number of imitations in this study. This study did not consider nutritional supplement intake from either the FFQ or the FR. Although a convenience sample was recruited of over 100 participants as recommended for validation studies (Nelson et al., 1997; Cade, 2002; Willett, 2012), the selection of volunteer participants may not represent the general population (Sharpe and Bradbury, 2015). For example, these participants may have been more motivated to complete the dietary assessments. Additionally, theses participants were relatively leaner compared to the NZ population aged between 65 and 74 years. Participants who were obese was 14.4% (BMI>30kg/m^2), whereas the obesity rate in the older adults aged 65 to 74 years in NZ is 32% (Sharpe and Bradbury, 2015; Ministry of Health, 2017). In NZ, 74% of the population identify as European, 15% as Māori, and 12% as Asian (Statistics NZ, 2014). However, the majority of the study participants were European (95%) meaning the FFQ should be validated in groups of other ethnicities prior to use.

3.6 Conclusions

In conclusion, the FFQ showed reasonable relative validity when compared against the 4DFR in older adults aged 65-74 years. The FFQ demonstrated good reproducibility for total energy and 28 nutrients. The FFQ is considered a valid dietary assessment tool for ranking nutrient intakes rather than assessing absolute intakes. The FFQ could be used in future studies regarding dietary intakes in older New Zealanders and associations with health outcomes. Recommendation for future validity studies of the FFQ should aim to validate across other ethnic groups living in New Zealand such as Māori, Pacific Island and Asian groups.

Chapter Four: Conclusion and Future Recommendations

An accurate and reliable dietary assessment tool is important for studies investigating the relationships between dietary intakes and health outcomes. However, it is challenging to assess dietary intake, particularly in older adults. Older adults may have difficulty in concentrating and responding appropriately to an FFQ with a comprehensive food list. Compared to younger people, older adults are less likely to have the ability to document usual dietary intakes due to disrupted memory (Thompson and Subar, 2001; Willett, 2012). To the best of our knowledge, an FFQ that focuses on assessing energy and multiple nutrient intakes specifically in older adults aged 65 to 74 years living in NZ has not been developed or validated; the latest validation study targeting older adults (n = 53) was undertaken nearly 30 years ago (Horwath, 1993).

The aim of this study was to assess the relative validity and reproducibility of an FFQ designed to measure relative nutrient intakes in older adults living in New Zealand. The semi-quantitative 109-item FFQ was compared against a four-day food record (4DFR) to assess validity. Nutrient intakes (n = 28) were adjusted for energy intakes; at least 50% of participants were correctly classified into the same tertiles for nine nutrients and less than 10% of participants were grossly misclassified into opposite tertiles for seven nutrients. Weighted kappa values improved moderately after energy adjustment with 19 nutrients showing fair agreement (κ = 0.21-0.40) and only eight nutrients showing poor agreement (κ <0.20). When compared with validation studies, the FFQ had similar results to studies undertaken in older adults internationally and in adults in NZ (Smith *et al.*, 1998; Carithers *et al.*, 2009; Sam *et al.*, 2014; Eysteinsdottir *et al.*, 2012). Overall, energy adjustment resulted in a moderate improvement on validity and reproducibility. The FFQ was administered twice four weeks apart and demonstrated good reproducibility. At least 50% of participants were correctly classified into the same tertiles and less than 10% of participants were grossly misclassified into opposite tertiles for energy and all nutrients (n = 28). Energy and most nutrient intakes (n = 25) between the FFQs showed moderate to good agreements (κ = 0.41-0.60) according to the weighted kappa values. In conclusion, the FFQ demonstrated reasonable relative validity and good reproducibility for a range of nutrients in older adults.

5.1 Strengths and limitations

One of the main strengths of the study was performing multiple statistical methods for the assessment of energy and nutrient validity and reproducibility as suggested by Cade *et al* (2002); the study included paired t-test, correlation coefficients, cross-classification, weighted kappa statistics, Bland-Altman plots, and linear regression analysis (Cade *et al*., 2002). Another strength was that all nutrients were adjusted for total energy intake. Similarly, energy adjustment performed in other studies have improved the validity and reproducibility of most nutrients. Adjustment for energy intake can control confounding effect, especially mis-reporting derived directly from energy intakes (Willett *et al*., 1997). Another strength of the study was the large sample size. A sample of 319 completed both FFQ1 and FFQ2, while 166 participants completed FFQ1 and the 4DFR. However, there are a number of limitations to the study. The participants had a lower BMI than the general population; only 14% of participants were categorised as obese (BMI>30 kg/m^2), whereas 32% of NZ adults aged 65 to 74 years were categorised as obese (Ministry of Health, 2017). The study participants comprised almost 95% European, therefore not an ideal representation of Māori, Pacific Islanders, and Asian groups. While the 4DFR was used as the reference method, the days recorded may not be long enough to sufficiently measure intake of nutrients such as vitamin A. This may explain low levels of correlations between the FFQ and 4DFR for some of the nutrients.

5.2 Significance of the study

This study is the first study to validate an FFQ assessing multiple nutrients against a food record and FFQ in older New Zealanders since 1992. From our findings, the FFQ is a reasonably accurate and highly reliable dietary assessment tool for assessing relative nutrient intake. The FFQ could then be used for older adults in both research and clinical settings.

5.3 Recommendation for future validity studies

There are a number of recommended approaches derived from the current study; these recommendations could be applied in future research to further improve the validity and reproducibility of the FFQ.

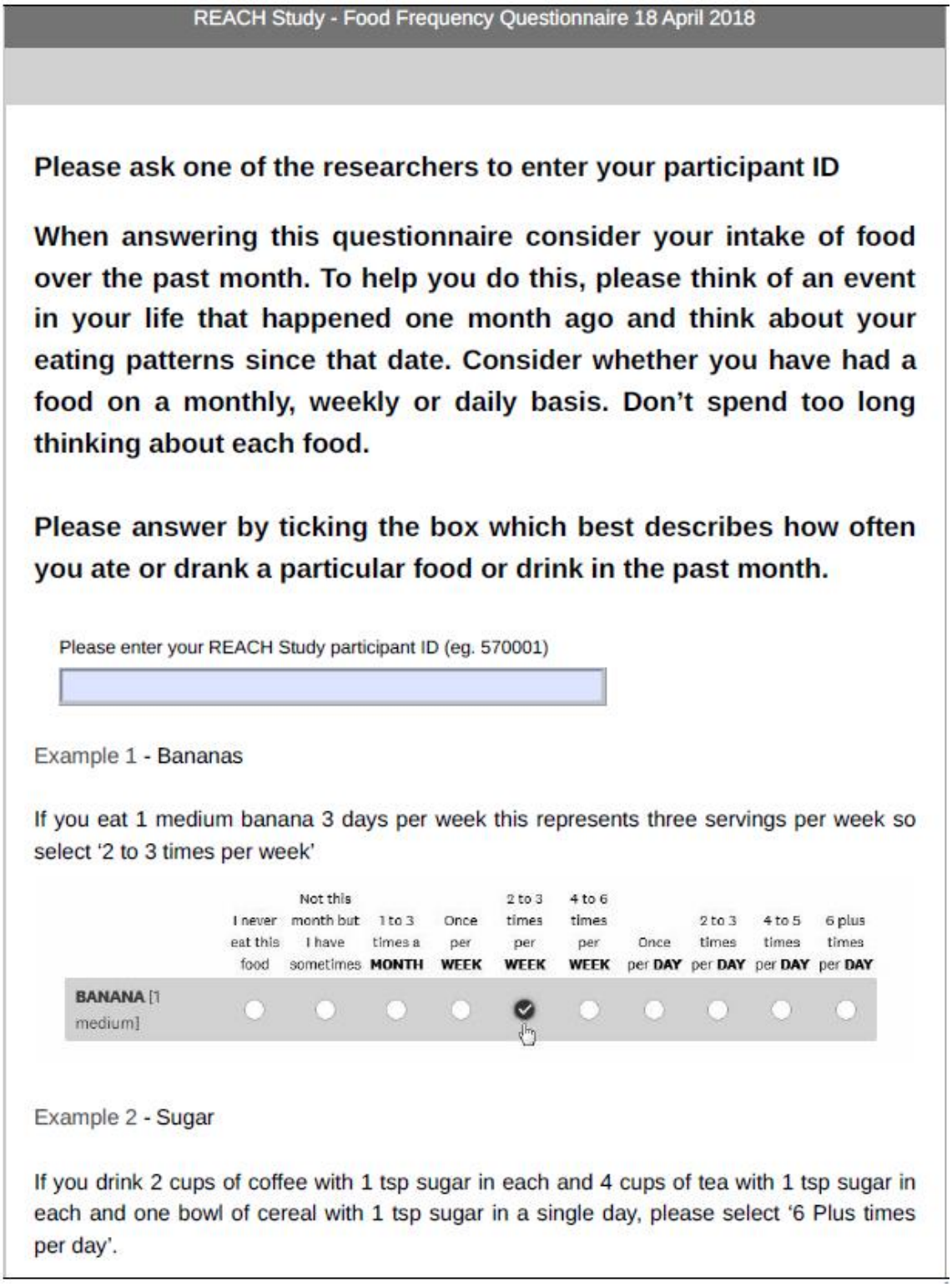
- Energy adjustment for nutrient intakes to improve the validity of FFQ. Future validity studies should adjust nutrients for total energy to control confounding effects of energy intake and reduce measurement errors from self-administered dietary assessment methods.
- Future research should evaluate whether the dietary assessment tool is culturally appropriate. If so, the FFQ should be validated across ethnic groups to ensure the best representation of the population.
- To validate an FFQ for specific nutrients, such as vitamin A or iron, future studies should consider a long-term food record with more recorded days (or more frequent 24-hour recalls) as the reference method. This will help ensure the accuracy of an FFQ for nutrients found in high amounts in few food sources which may be consumed in large amounts during a short period.
- Further modification of the FFQ may improve the accuracy of measured nutrient intakes. For example, mango and pumpkin have higher levels of vitamin A than other fruits and vegetables categorised in the same group, a separate food frequency question assessing these specific items may refine the measured nutrient intakes from the FFQ.

In conclusion, the semi-quantitative FFQ is a reasonably robust and cost-effective dietary assessment tool for measuring relative nutrient intakes in older adults living in New Zealand. Although poor validity correlations were observed for some nutrients (selenium, potassium, iron and folate), the FFQ was relatively valid for measuring multiple other nutrients. The FFQ demonstrated good reproducibility when compared with the FFQ re-administered four weeks later. When nutrients were adjusted for energy intake, the 109-item FFQ showed moderate improvements for both relative validity and reproducibility for the majority of nutrients.

Chapter Five: Appendices

Appendix A: Food frequency questionnaire (FFQ)

The full version of the food frequency questionnaire is available on request at Massey University.



REACH Study - Food Frequency Questionnaire 18 April 2018

Please ask one of the researchers to enter your participant ID

When answering this questionnaire consider your intake of food over the past month. To help you do this, please think of an event in your life that happened one month ago and think about your eating patterns since that date. Consider whether you have had a food on a monthly, weekly or daily basis. Don't spend too long thinking about each food.

Please answer by ticking the box which best describes how often you ate or drank a particular food or drink in the past month.

Please enter your REACH Study participant ID (eg. 570001)

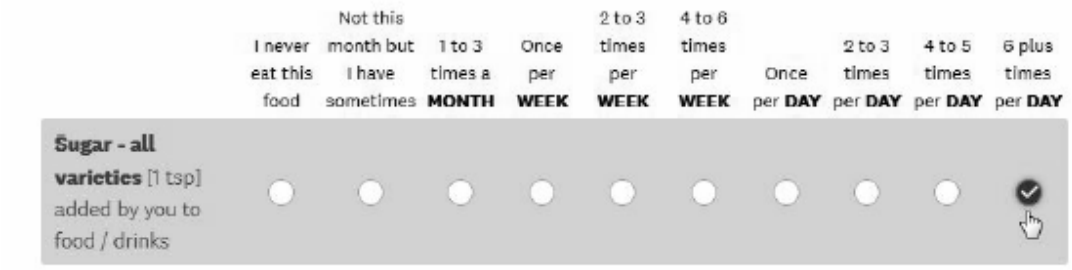
Example 1 - Bananas

If you eat 1 medium banana 3 days per week this represents three servings per week so select '2 to 3 times per week'

	I never eat this food	Not this month but I have sometimes	1 to 3 times a **MONTH**	Once per **WEEK**	2 to 3 times per **WEEK**	4 to 6 times per **WEEK**	Once per **DAY**	2 to 3 times per **DAY**	4 to 5 times per **DAY**	6 plus times per **DAY**
BANANA [1 medium]	○	○	○	○	✓	○	○	○	○	○

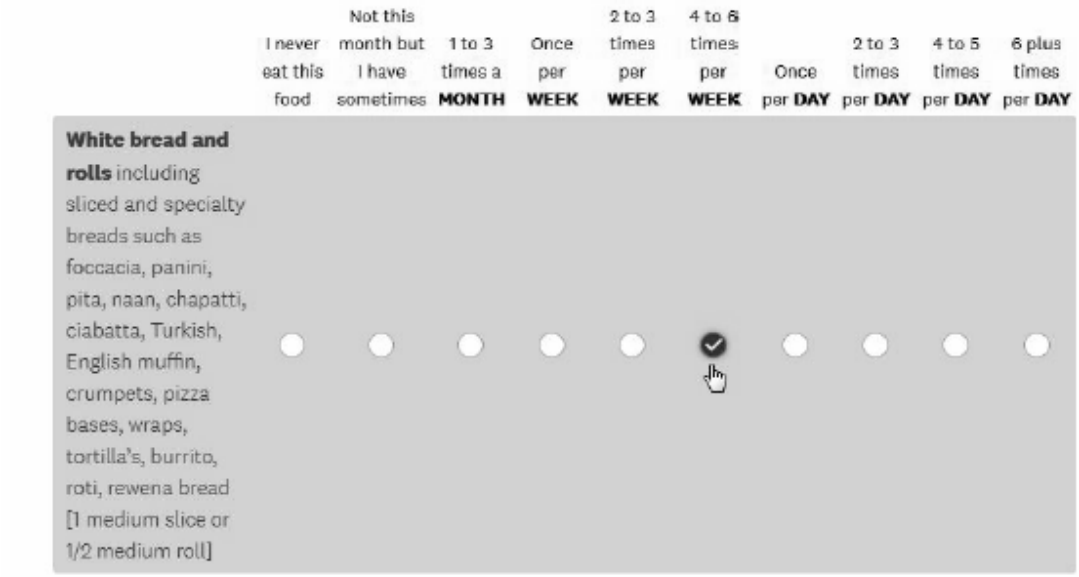
Example 2 - Sugar

If you drink 2 cups of coffee with 1 tsp sugar in each and 4 cups of tea with 1 tsp sugar in each and one bowl of cereal with 1 tsp sugar in a single day, please select '6 Plus times per day'.



Example 3 - White bread and rolls

If eating 2 medium slices of bread two times per week this represents four servings per week so select "4 to 6 times per week".



REACH Study - Food Frequency Questionnaire 18 April 2018

The questionnaire starts here.

FRUIT

* In the past month I have had this food

	I never eat this food	Not this month but I have sometimes	1 to 3 times a **MONTH**	Once per **WEEK**	2 to 3 times per **WEEK**	4 to 6 times per **WEEK**	Once per **DAY**	2 to 3 times per **DAY**	4 to 5 times per **DAY**	6 plus times per **DAY**
Apples, pears, nashi pears [1 medium]	○	○	○	○	○	○	○	○	○	○
Banana [1 medium]	○	○	○	○	○	○	○	○	○	○
Citrus fruits e.g. orange, tangelo, tangerine, mandarin, grapefruit, lemon, lime [1 medium or 2 small]	○	○	○	○	○	○	○	○	○	○
Stone fruit e.g. apricots, nectarines, peaches, plums, lychees [1 medium or 2 small]	○	○	○	○	○	○	○	○	○	○
Avocado [1/4 avocado]	○	○	○	○	○	○	○	○	○	○
Olives [4 olives]	○	○	○	○	○	○	○	○	○	○
Strawberries, blackberries, cherries, blueberries, boysenberries, loganberries, cranberries, gooseberries, raspberries (fresh, frozen, canned) [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Dried fruit e.g. sultanas, raisins, currants, figs, apricots, prunes, dates [2 Tbsp]	○	○	○	○	○	○	○	○	○	○
All other fruit e.g. feijoa, persimmon, tamarillo, kiwifruit, grapes, mango, melon, watermelon, pawpaw, papaya, pineapple, rhubarb [1 medium or 1/2 cup]	○	○	○	○	○	○	○	○	○	○

VEGETABLES

* In the past month I have had this food

	I never eat this food	Not this month but I have sometimes	1 to 3 times a **MONTH**	Once per **WEEK**	2 to 3 times per **WEEK**	4 to 6 times per **WEEK**	Once per **DAY**	2 to 3 times per **DAY**	4 to 5 times per **DAY**	6 plus times per **DAY**
Potato e.g. boiled, mashed, baked, jacket, instant, roasted [1 medium or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Hot potato chips, French fries, wedges [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Kumara, taro, green banana, cassava e.g. boiled, mashed, baked, roasted [1 medium or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Carrots [1 medium or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Other root vegetables e.g. yams, parsnip, swedes, beetroot, turnips [1 medium or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Peas, green [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Green beans, broad beans, runner beans [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Broccoli, cauliflower, brussel sprouts, cabbage (all varieties) [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Salad vegetables e.g. lettuce, cucumber, celery, sprouts [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Green leafy vegetables e.g. spinach, silver beet, swiss chard, watercress, puha, Whitloof, chicory, kale, chard, collards, Chinese kale, Bok Choy, taro leaves (palusami) [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Tomatoes (all varieties) [1 medium or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
All other vegetables e.g. corn, pumpkin, mushrooms, capsicum, peppers, courgette, zucchini, gerkins, marrow, squash, asparagus, radish, eggplant, artichoke [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Onions, leeks, garlic [1 Tbsp]	○	○	○	○	○	○	○	○	○	○

MEAT and CHICKEN

* In the past month I have had this food

	I never eat this food	Not this month but I have sometimes	1 to 3 times a **MONTH**	Once per **WEEK**	2 to 3 times per **WEEK**	4 to 6 times per **WEEK**	Once per **DAY**	2 to 3 times per **DAY**	4 to 5 times per **DAY**	6 plus times per **DAY**
Beef, lamb, hogget, mutton, pork, veal e.g. roast, steak, fried, chops, schnitzel, silverside, casserole, stew, stir fry, curry, BBQ, hamburger meat, mince dishes, frozen dinners [Palm size or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Chicken, turkey or duck e.g. roast, steak, fried, steamed, BBQ, casserole, stew, stir fry, curry, mince dishes, frozen dinners [Palm size or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Liver, kidney, other offal (including pate) [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Sausages, frankfurters, cheerios, hot dogs [1 medium sausage]	○	○	○	○	○	○	○	○	○	○
Ham, bacon, luncheon sausage, salami, pastrami, other processed meat [2 medium slices]	○	○	○	○	○	○	○	○	○	○
Corn beef (canned), boil up, pork bones, lamb flaps, povi masima [Palm size or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Meat pies, sausage rolls [1 meat pie or 2 sausage rolls]	○	○	○	○	○	○	○	○	○	○

FISH and SEAFOOD

* In the past month I have had this food

	I never eat this food	Not this month but I have sometimes	1 to 3 times a **MONTH**	Once per **WEEK**	2 to 3 times per **WEEK**	4 to 6 times per **WEEK**	Once per **DAY**	2 to 3 times per **DAY**	4 to 5 times per **DAY**	6 plus times per **DAY**
Fish fried in batter (from fish & chips shop) [1 piece of palm size fish]	○	○	○	○	○	○	○	○	○	○
Albacore tuna, salmon, sardines, herring, kahawai, swordfish, carp, dogfish, gemfish, Alfonsino, rudderfish, anchovies [Palm size or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Mackerel, snapper, oreo, barracouta, trevally, dory, trout, eel [Palm size or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Tuna (canned), hoki, gurnard, hake, kingfish, cod, tarakihi, groper, flounder [Palm size or 1/2 cup]	○	○	○	○	○	○	○	○	○	○
Crumbed fish e.g. patties, cakes, fingers, nuggets [1 patty/cake or 2 fingers/nuggets]	○	○	○	○	○	○	○	○	○	○
Green mussels, squid [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Shellfish e.g. cockles, kina, oysters, paua, scallops, shrimp/prawn, pipi, roe [1/2 cup]	○	○	○	○	○	○	○	○	○	○

EGG, NUTS, SOY and LEGUMES

* In the past month I have had this food

	I never eat this food	Not this month but I have sometimes	1 to 3 times a **MONTH**	Once per **WEEK**	2 to 3 times per **WEEK**	4 to 6 times per **WEEK**	Once per **DAY**	2 to 3 times per **DAY**	4 to 5 times per **DAY**	6 plus times per **DAY**
Eggs – boiled, poached, raw [1 egg]	○	○	○	○	○	○	○	○	○	○
Eggs - fried, scrambled, egg based dishes including quiche, soufflés, frittatas, omelets [1 egg]	○	○	○	○	○	○	○	○	○	○
Nuts e.g. peanuts, mixed nuts, macadamias, pecan, hazelnuts, brazil nuts, walnuts, cashews, pistachios, almonds [1 Tbsp]	○	○	○	○	○	○	○	○	○	○
Seeds e.g. pumpkin seeds, sunflower seeds, pinenuts, sesame seeds, tahini [1 Tbsp]	○	○	○	○	○	○	○	○	○	○
Nut butters or spreads e.g. peanut butter, almond butter, pesto [1 tsp]	○	○	○	○	○	○	○	○	○	○
Tofu, soybeans, tempeh [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Beans (canned or dried) e.g. black beans, butter beans, haricot beans, kidney beans, cannellini beans, refried beans, baked beans, chilli beans [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Peas and lentils e.g. chickpeas, hummus, falafels, split peas, cow peas, dahl [1/2 cup]	○	○	○	○	○	○	○	○	○	○
Vegetarian sausages / meat, vegetarian burger patty, textured vegetable protein [1 sausage or 1 patty]	○	○	○	○	○	○	○	○	○	○

REACH Study - Food Frequency Questionnaire 18 April 2018

* Are there any other foods which you have eaten in the past month?

- Yes
- No

If yes, please state the food, the serving size and the frequency of consumption

Food (A)

Serving size (Food A)

Frequency of comsumption (Food A)

Food (B)

Serving size (Food B)

Frequency of comsumption (Food B)

Food (C)

Serving size (Food C)

Frequency of comsumption (Food C)

REACH Study - Food Frequency Questionnaire 18 April 2018

We now have a few more questions to ask about your dietary intake. Some may seem similar to the above questions, but please still answer them.

* **On average how many servings of breads, cereals and grains (rice, pasta, quinoa, couscous, breads, wraps, rewena, chapatti, roti, breakfast cereals, tapioca, sago, amaranth, congee) do you eat per day?**

A serving is 1 slice bread, 1/2 cup cooked rice or pasta

E.g. 4 slices bread + 1 cup of pasta = 6 servings (6 or more servings).

- ○ Never, I don't eat breads, cereals or grains
- ○ Less than one serving per day
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 servings
- ○ 6 or more servings
- ○ Don't know

Appendix B: Four-day food record (4DFR)

Participant ID

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

The REACH (Researching Eating Activity and Cognitive Health) Study

4 Day Food Record

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

If you have any questions, please contact Kathryn Beck on (09) 414 0800 ext 43662 or email reachstudy@massey.ac.nz

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

Participant ID

What to do?

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

_____

_____

_____

_____

_____

- 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.
- Include any supplements (brand name, type, number taken, etc)
- 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.

Participant ID

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 food record and be honest! Your food record will be identified with a number rather than your name.***

Example day

Time and place food was eaten	Complete description of food (food and beverage name, brand, variety, preparation method) Complete description of training	Amount consumed (units, measures, weight)
Example 7:55am At home	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 In car	Raw Apple (gala)	Ate all of apple except the core, whole apple was 125g (core was ¼ of whole apple)
12.00pm At home	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 At work	Water	500ml plain tap water
3.00pm At work	Biscuits	6 x chocolate covered Girl Guide biscuits (standard size)
6.00pm At home	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 At home	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 At home	Coffee	1 tsp Gregg's instant coffee 1 x 300ml cup of water 2 Tbsp Meadow fresh blue top milk 2 tsp sugar

Participant ID

Date_____ DAY 1

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

Participant ID

Date_____ DAY 1 continued

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

Participant ID

Recipes (Day 1)

Appendix C: Assumption list for food record entry

Data entry and management: To ensure the quality of the 166 food records, 10% of food records were fully checked by another researcher. All food records were then checked for outliers in energy and 28 nutrient intakes. Outliers that were not within the normal distribution were investigated and correction was undertaken where necessary (for example, fixing incorrect units or food items).

Table 5.1 List of assumptions for food records and selected food items entered in FoodWorks

Food item from the 4DFR	Example/brands/details	Correct Substitution	Database[1]
Grains			
Mixed grain bread	Generic/supermarket brands (e.g. Value)	Bread, mixed grain, light, sliced, prepacked	NZ FoodFiles
Wholemeal bread	Generic/supermarket brands (e.g. Value)	Bread, wholemeal, toasted	NZ FoodFiles
Rolled oats		Oats, rolled, raw	NZ FoodFiles
Wholegrain oats	Generic/supermarket brands (e.g. Value)	Oats, wholegrain, raw	NZ FoodFiles
Sourdough bread		Bakerboys White Sourdough	AusBrands 2017
White bread	If brand unspecified	Bread, white, sliced, prepacked	NZ FoodFiles
Bagel	If brand unspecified	Bagels, white, plain	NZ FoodFiles
Wraps	If brand unspecified	Bread, pita, white	NZ FoodFiles
White flour	Generic	Flour, wheat, white	NZ FoodFiles
Dairy and alternatives			
Blue top milk	Generic - if no brand is available	Milk, cow, standard 3.3% fat, fluid	NZ FoodFiles
Light blue top milk	Generic - if no brand is available	Milk, cow, lite 1.5% fat, fluid	NZ FoodFiles
Yellow top milk		Milk, cow, high calcium 0.1% fat, fluid, fortified	NZ FoodFiles
Salted butter	Generic - if no brand is available	Butter, salted	NZ FoodFiles
Margarine	If brand unspecified	Margarine,polyunsaturated,70% fat, fortified	NZ FoodFiles
Green top milk	Generic - if no brand is available	Milk, cow, trim 0.5% fat, fluid	NZ FoodFiles
Biofarms acidophilus organic yoghurt		Yoghurt, plain, unsweetened	NZ FoodFiles
Gopala Yoghurt		Yoghurt, plain, unsweetened	NZ FoodFiles
Yoghurt protein	Protein+ yoghurt	Dairy Dream Hi-Protein Yoghurt Natural	AusBrands 2017

Food item from the 4DFR	Example/brands/details	Correct Substitution	Database[1]
Skim milk Powder		Milk, cow, powder, instant, skim	NZ FoodFiles
Fruit			
Banana		Banana, yellow, ripened, raw	NZ FoodFiles
Blueberry	Frozen	Blueberry, frozen	NZ FoodFiles
	Raw	Blueberry, raw	NZ FoodFiles
Kiwifruit	Green	Kiwifruit, Zespri Green (Hayward) Kiwifruit, Zespri, raw	NZ FoodFiles
	Gold	Kiwifruit, Zespri Gold (Hort16A) Kiwifruit, Zespri, raw	NZ FoodFiles
Mango	Raw	Mango, flesh, raw	NZ FoodFiles
Apricot	Raw	Apricot, Raw	AusBrands
Avocado	Raw	Avocado, flesh, raw	NZ FoodFiles
Lemon Juice		Juice, lemon, raw	NZ FoodFiles
Vegetables			
Garlic		Garlic, cloves, raw, peeled	NZ FoodFiles
Mesclun	Raw	Salad, Mesclun, leaves, raw	NZ FoodFiles
Tomato		Tomato, whole, raw	NZ FoodFiles
Carrot	Raw	Carrot, flesh, fresh, raw	NZ FoodFiles
Broccoli	Raw	Broccoli, raw	NZ FoodFiles
	Boiled steamed	Broccoli, boiled, drained, no salt added	NZ FoodFiles
Mushroom	Fresh/stir fried	Mushroom, raw	NZ FoodFiles
Eggs			
Eggs - poached		Egg, chicken, white & yolk, poached	NZ FoodFiles
Meat			
Any meat/chicken/fish	If quantity not provided	100g as standard serve estimate	
Bacon Hock		Courtway Smoked Hocks	AusBrands 2017
Chicken breast	Cooked, skin removed	Chicken, breast, flesh, roasted	NZ FoodFiles
Nuts/seeds			
Chia seed	Generic	Seeds, chia, dried	AusFood 2017
Linseed	Generic	Seeds, linseed	AusFood 2017

Food item from the 4DFR	Example/brands/details	Correct Substitution	Database[1]
Pumpkin seed	Generic	Seeds, pumpkin	AusFood 2017
Sunflower seed	Generic	Seeds, sunflower	AusFood 2017
Sesame seed	Generic	Seeds, sesame	NZ FoodFiles
Beverages			
Instant coffee		Coffee, instant, dry powder	NZ FoodFiles
Plunger coffee		Coffee, instant, dry powder	NZ FoodFiles
Espresso		Coffee beverage, espresso, cafe variety	NZ FoodFiles
Flat white	Small café style	Coffee beverage, flat white, double shot & milk standard 3.3% fat, 190 mL, cafe variety	NZ FoodFiles
Flat white - trim	Small café style	Coffee beverage, flat white, double shot & milk trim 0.5% fat,190 mL, cafe variety	NZ FoodFiles
Water		Water, tap	NZ FoodFiles
Black tea		Tea, black, regular, plain, without milk	NZ FoodFiles
Earl Grey Tea		Diplomat Earl Grey 50 Tea Bags	AusFood 2017
Decaf Coffee	Greggs Decaf	Nescafe Blend 43 Decaf	AusFood 2017
Green tea		Tea beverage, green	NZ FoodFiles

[1]From FoodWorks 9 Professional; NZ FoodFiles, New Zealand Food Composition Database 2016; AusFood 2017 and AusBrands 2017, generic food database from FoodWorks Professional (version 9, 2018, Xyris Software).

Appendix D: Food mapping process for the food frequency questionnaire

Food items (n = 109) from the FFQ were mapped for its corresponding food selected from the food database in FoodWorks. Twenty were a combination of multiple food items, seven used food items from the Australia food database, and the remainder were based on New Zealand FOODFiles. New composites were developed when one single food item (NZ database) was unable to describe the FFQ food item. For example, for the question regarding broccoli, cauliflower, Brussel sprouts, and cabbage intake, a new composite was created using equal ratios of each vegetable (Table 2); stone fruit was mapped using a combination of four different types of stone fruits, equal ratios of each.

Table 5.2 List of 109 food items from FFQ and the according food mapping description (FoodWorks)

Food frequency questionnaire food item	Mapped food item (Food database[1])	Composite ratios
Apples, pears, nashi pears	Apple, flesh & skin, raw, combined varieties	
Banana	Banana, yellow, ripened, raw	
Citrus fruits e.g. orange, tangelo, tangerine, mandarin, grapefruit, lemon, lime	▪ Mandarin, flesh, raw ▪ Orange, flesh, raw, USA (imported)	50% each
Stone fruit e.g. apricots, nectarines, peaches, plums, lychees	▪ Plum, flesh & skin, raw ▪ Peach, flesh & skin, raw ▪ Nectarine, flesh & skin, raw ▪ Apricot, flesh & skin, raw	25% each
Avocado	Avocado, flesh, raw	
Olives	▪ Olive, green, plain, in oil ▪ Olive, in brine	50% each
Strawberries, blackberries, cherries, blueberries, boysenberries, loganberries, cranberries, gooseberries, raspberries	▪ Strawberry, raw, New Zealand ▪ Blueberry, raw	50% each
Dried fruit e.g. sultanas, raisins, currants, figs, apricots, prunes, dates	Raisin, seedless	

Food frequency questionnaire food item	Mapped food item (Food database[1])	Composite ratios
All other fruit e.g. feijoa, persimmon, tamarillo, kiwifruit, grapes, mango, melon, watermelon, pawpaw, papaya, pineapple, rhubarb	▪ Kiwifruit, green, flesh & seed, raw, Bruno ▪ Grape, red or green, seedless, raw, European type ▪ Feijoa, flesh, raw ▪ Melon, Cantaloupe, flesh, raw ▪ Rhubarb, raw	20% each
Potato e.g. boiled, mashed, baked, jacket, instant, roasted	Potato, flesh, floury, boiled, drained, mashed, no salt added	
Hot potato chips, French fries, wedges	Fries, potato, straight cut, Independent Shops	
Carrots	Carrot, flesh, fresh, steamed	
Other root vegetables e.g. yams, parsnip, swedes, beetroot, turnips	▪ Beetroot, canned in water, sliced, drained ▪ Parsnip, flesh, steamed	50% each
Peas, green	Pea, green, frozen, boiled, drained, no salt added	
Green beans, broad beans, runner beans	Bean, green runner or dwarf, seeds with pod, fresh, steamed	
Broccoli, cauliflower, Brussel sprouts, cabbage (all varieties)	▪ Broccoli, boiled, drained, no salt added ▪ Cauliflower, boiled, drained, no salt added ▪ Brussels sprout, boiled, drained, no salt added ▪ Cabbage, green drumhead, leaves, boiled, drained, no salt added	25% each
Salad vegetables e.g. lettuce, cucumber, celery, sprouts	▪ Lettuce, Cos, raw ▪ Cucumber, Telegraph, raw, unpeeled ▪ Celery, American Green, stalk, raw	33.3% each
Green leafy vegetables e.g. spinach, silver beet, Swiss chard, watercress, puha, Whitloof, chicory, kale, chard, collards, Chinese kale, Bok Choy, taro leaves	Spinach, English, boiled, drained, no salt added	
Tomatoes (all varieties)	Tomato, whole, raw	
All other vegetables e.g. corn, pumpkin, mushrooms, capsicum, peppers, courgette, zucchini, gerkins, marrow, squash, asparagus, radish, eggplant, artichoke	▪ Sweet corn, kernel, fresh, boiled, drained, no salt added ▪ Pumpkin, flesh, boiled, drained, no salt added ▪ Mushroom, raw ▪ Capsicum, Red, raw ▪ Courgette, Green, unpeeled, raw	20% each
Onions, leeks, garlic	Onion, flesh, boiled, drained, no salt added	

Food frequency questionnaire food item	Mapped food item (Food database[1])	Composite ratios
Beef, lamb, hogget, mutton, pork, veal e.g. roast, steak, fried, chops, schnitzel, silverside, casserole, stew, stir fry, curry, BBQ, hamburger meat, mince dishes, frozen dinners	Beef, hindquarter skirt steak, separable lean, braised	
Chicken, turkey or duck e.g. roast, steak, fried, steamed, BBQ, casserole, stew, stir fry, curry, mince dishes, frozen dinners	Chicken, breast, lean & fat, roasted	
Liver, kidney, other offal (including pate)	Lamb, offal, lambs fry, fried	
Sausages, frankfurters, cheerios, hot dogs	Sausage, assorted meats & flavours, grilled	
Ham, bacon, luncheon sausage, salami, pastrami, other processed meat	Ham, sliced	
Corn beef (canned), boil up, pork bones, lamb flaps, povi masima	Beef, corned silverside, shaved & sliced, deli	
Meat pies, sausage rolls	Pie, mince, individual size, ready to eat, commercial	
Fish fried in batter (from fish & chips shop)	Fish, battered, deep fried, Independent Shops	
Albacore tuna, salmon, sardines, herring, kahawai, swordfish, carp, dogfish, gemfish, Alfonsino, rudderfish, anchovies	Salmon, king, fillet, skin & bones removed, fresh, baked without fat, no salt added, New Zealand	
Mackerel, snapper, oreo, barracouta, trevally, dory, trout, eel	Snapper, flesh, baked	
Tuna (canned), hoki, gurnard, hake, kingfish, cod, tarakihi, groper, flounder	▪ Tarakihi, flesh, baked ▪ Tuna, canned in spring water, plain, salt added, drained	50% each
Crumbed fish e.g. patties, cakes, fingers, nuggets	Fish, fillet, crumbed, frozen, fried	
Green mussels, squid	Mussel, green, meat, marinated, assorted flavoured, drained, ready to eat, Sealord	
Shellfish e.g. cockles, kina, oysters, paua, scallops, shrimp/prawn, pipi, roe	▪ Scallop, raw ▪ Oyster, Pacific, flesh, raw ▪ Prawn, king, flesh, cooked ▪ Shrimp, boiled	25% each
Eggs – boiled, poached, raw	Egg, chicken, white & yolk, poached	
Eggs - fried, scrambled, egg based dishes including quiche, soufflés, frittatas, omelettes	Egg, chicken, white & yolk, fried in vegetable oil	

Food frequency questionnaire food item	Mapped food item (Food database[1])	Composite ratios
Nuts e.g. peanuts, mixed nuts, macadamias, pecan, hazelnuts, brazil nuts, walnuts, cashews, pistachios, almonds	Nut, mixed, salted	
Seeds e.g. pumpkin seeds, sunflower seeds, pinenuts, sesame seeds, tahini	*Seeds, mixed	
Nut butters or spreads e.g. peanut butter, almond butter, pesto	Peanut butter, smooth & crunchy, salt added, no sugar added	
Tofu, soybeans, tempeh	Tofu, soy bean curd, regular, firm, simmered or pouched, no salt added	
Beans (canned or dried) e.g. black beans, butter beans, haricot beans, kidney beans, cannellini beans, refried beans, baked beans, chilli beans	Bean, mixed beans, canned in brine, drained	
Peas and lentils e.g. chickpeas, hummus, falafels, split peas, cow peas, dahl	Chickpea, cooked	
Vegetarian sausages / meat, vegetarian burger patty, textured vegetable protein	*Sausage, vegetarian, unfortified, baked	
Bran based cereals, muesli, porridges – e.g. rolled oats, oat bran, oat meal, All Bran, Sultana bran	▪ Porridge, prepared with water, salt added ▪ Sultana Bran, Kellogg's, fortified ▪ Toasted Muesli Golden Oats & Fruit, Sanitarium	33.3% each
Weet-bix, cornflakes or rice bubbles	▪ Weet-Bix Oat Bran, Sanitarium, fortified ▪ Skippy Cornflakes, Sanitarium, fortified ▪ Rice Bubbles, Kellogg's, fortified	33.3% each
Sweetened cereals e.g. Nutrigrain, Fruit Loops, Honey Puffs, Frosties, Milo cereal, CocoPops	Nutri-Grain, Kellogg's, fortified	
Other breakfast cereals e.g. Special K, Light and tasty	Light 'n' Tasty, Sanitarium, fortified	
White rice	Rice, white, polished, boiled	
Brown rice	Rice, brown, boiled	
White pasta, noodles e.g. spaghetti, canned spaghetti, vermicelli, egg noodles, rice noodles, instant noodles	Pasta, white wheat flour, assorted shapes, regular, boiled, drained, no salt added	
Whole meal pasta, noodles	Pasta, wholemeal wheat flour, assorted shapes, boiled, drained, no salt added	
Couscous, polenta, congee, Bulgur wheat, quinoa e.g. tabbouleh	Couscous, white wheat, cooked in water, not drained, no salt or fat added	

Food frequency questionnaire food item	Mapped food item (Food database[1])	Composite ratios
Pancakes, waffles, sweet buns, scones, sweet muffins, fruit bread, croissants, doughnuts, brioche	*Muffin, plain, commercial	
White bread and rolls including sliced and specialty breads such as foccacia, panini, pita, naan, chapatti, ciabatta, Turkish, English muffin, crumpets, pizza bases, wraps, tortilla's, burrito, roti, rewena bread	Bread, wheat, white, prepacked, upper North Island	
Whole meal or wheat meal bread and rolls including sliced and specialty breads	Bread, wheat, white, prepacked, upper North Island	
Whole grain or multi grain bread and rolls including sliced and specialty breads	Bread, mixed grain, light, sliced, prepacked	
Crackers e.g. crisp bread, water crackers, rice cakes, cream crackers, Cruskits, Mealmates, Vitawheat	Cracker, wheat, Supreme, Arnott's & Somerset, Huntley & Palmers	
Cheese e.g. Cheddar, Colby, Edam, Tasty, blue vein, camembert, parmesan, gouda, feta, mozzarella, brie, processed	Cheese, Edam	
Cottage cheese, ricotta cheese	Cheese, Cottage	
Cream, sour cream, cream cheese, cheese spreads	Cheese, Cream	
Cow's milk including milk as a drink, milk added to drinks	Milk, cow, standard 3.3% fat, fluid	
Soy milk, coconut milk, rice milk, almond milk	▪ Soy milk, So Good Regular Soy Milk, Sanitarium, fortified ▪ Coconut, milk, standard ▪ Rice milk, Rice Drink Original, Rice Dream, fortified	33.3% each
Smoothies, milk shakes (made from milk, yoghurt, ice cream), milk shakes, flavoured milk	▪ Smoothie, berry, fortified. ▪ Milk, cow, chocolate flavour, fluid, ultra-high-temperature processed.	50% each
Milk based puddings e.g. rice pudding, custard, semolina, instant puddings, dairy food	Dessert, assorted flavours, dairy food	
Yoghurt	Yoghurt, premium, assorted fruits	
Ice cream	Ice cream, vanilla, standard	
Hot chocolate, drinking chocolate, Cocoa, Ovaltine, Nesquik, Milo	*Drinking chocolate, from regular powder, with reduced fat milk	
Coffee (all varieties)	Coffee beverage, instant, dry powder with water & milk standard 3.3% fat	

Food frequency questionnaire food item	Mapped food item (Food database[1])	Composite ratios
Tea	Tea beverage, black	
Herbal tea, fruit tea	Tea beverage, herbal, brewed	
Low calorie cordials	*Cordial, fruit cup, diet	
Cordials including syrups, powders e.g. Raro	▪ *Cordial, other, citrus fruit, 25% fruit juice, regular ▪ Juice concentrate, Lemon & Barley Syrup, Barkers, fortified ▪ Water, tap.	50% 8% 42%
Fruit and vegetable juices (all varieties)	Juice, apple and orange, unsweetened, Fresh Up, fortified	
Sports drinks e.g. Powerade	Sports drink, ready to drink, Powerade	
Energy drinks e.g. Red Bull, V	Energy drink, assorted flavours, V, Frucor, fortified	
Diet soft/fizzy drinks e.g. Sprite Zero, Diet Coke, Coke Zero	Soft drink, carbonated, lemon flavour, artificially-sweetened	
Soft/fizzy drinks e.g. Sprite, Coke	Soft drink, cola flavour, sugar-sweetened, caffeinated	
Water including tap, bottled or sparkling water	Water, tap	
Beer, lager, cider (all varieties)	Beer, mid-strength (4% alcohol by volume)	
Red wine	Wine, red, (13.5% alcohol by volume), Pinot Noir	
White wine	Wine, white, dry, (12% alcohol by volume), Sauvignon Blanc	
Port, sherry, liquors	Sherry, medium	
Spirits e.g. gin, brandy, whiskey, vodka	Spirit,70 proof	
Ready to drink alcoholic beverages	*Mixed alcoholic drink, rum & cola	
Cakes, slices, pastries	Cake, fruitcake	
Non-milk based puddings e.g. pavlova, sweet pastries, fruit pies, trifle	▪ Pudding, sponge, steamed ▪ *Pavlova, base, commercial	50% each
Biscuits, plain	Biscuit, Arrowroot	

Food frequency questionnaire food item	Mapped food item (Food database[1])	Composite ratios
Biscuits, chocolate or cream filled	Biscuit, with cream filling	
Butter, ghee	Butter, salted	
Margarine	▪ Margarine, monounsaturated, 75% fat, Olivani ▪ Margarine, polyunsaturated, 70% fat, fortified	50% each
Vegetable oils	Oil, vegetable, blend, salad & cooking	
Sugar (all varieties) added by you to food / drinks	Sugar, castor	
Jam, marmalade, honey, syrups, sweet spreads or preserves	Jam, berry fruit	
Marmite, vegemite	Spread, yeast extract, Marmite, Sanitarium, fortified	
Coconut cream	Coconut, cream, premium	
Coconut oil	Coconut oil	
Creamy dressings e.g. mayonnaise, tartar, thousand island, ranch dressing	Dressing, potato salad, Eta	
Light dressings e.g. French and Italian dressing, balsamic vinegar	Dressing, French, Kraft	
White sauce, cheese sauce, gravies	▪ *Sauce, cheese ▪ *Gravy, ready to eat, regular	50% each
Tomato sauce, barbeque sauce, sweet chilli sauce	Sauce, tomato, Ketchup	
Pickles, chutney, mustard	Pickle, sweet	
Spices e.g. turmeric, ginger, cinnamon	Spice, cinnamon, ground	
Soup, homemade or canned	Soup, vegetable, canned	
Muesli or cereal bar (all varieties)	▪ Muesli bar, fruit & nut ▪ Muesli bar, fruit filled, wholemeal, assorted flavours	50% each
Potato crisps	Potato chip or crisp, plain, salted, fried in assorted oils	
Sweets, lollies	▪ Pastille, hard candy ▪ Lollies, Minties, Pascall	50% each

Food frequency questionnaire food item	Mapped food item (Food database[1])	Composite ratios
Chocolate (all other varieties)	Chocolate, milk chocolate, Dairy Milk, Cadbury	

[1]From NZ FoodFiles as default or generic food database from FoodWorks Professional (version 9, 2018, Xyris Software). *Food items unavailable from the NZ FoodFiles replaced with alternative options from the Australia food database. For example, the New Zealand database only had drinking hot chocolate in powder form, “Hot chocolate powder”, thus was replaced with liquid form “Drinking chocolate, from regular powder, with reduced fat milk”.

Appendix E: Supplementary results tables

Supplementary Table 1 Regression analysis of nutrient intakes in FFQ1 and 4DFR (n=166)

Nutrient	Raw				Adjusted			
	Significance (*p*-value)	Unstandardized coefficients (β)	SE	LOA (95% Confidence Interval)	Significance (*p*-value)	Unstandardized coefficients (β)	SE	LOA (95% Confidence Interval)
Energy	0.003	-0.33	0.11	-0.54, -0.11	-	-	-	-
Protein	0.001	-0.34	0.10	-0.53, -0.14	0.533	0.06	0.10	-0.14, 0.27
Carbohydrate	0.130	-0.14	0.09	-0.13, 0.04	0.056	0.15	0.08	0.0, 0.31
Sugars	<0.001	-0.38	0.10	-0.58, -0.19	0.972	-0.00	0.10	-0.20, 0.20
Dietary fibre	<0.001	-0.09	0.10	-0.28, 0.10	0.568	-0.05	0.09	-0.22, 0.12
Alcohol	0.350	0.33	0.07	0.19, 0.47	<0.001	2.09	0.24	1.63, 2.56
Total fat	0.565	-0.07	0.13	-0.32, 0.17	0.042	0.20	0.10	0.01, 0.39
SAFA	0.006	-0.33	0.12	-0.57, -0.10	0.891	0.02	0.11	-0.20, 0.23
MUFA	0.003	0.34	0.11	0.12, 0.57	<0.001	0.38	0.10	0.19, 0.56
PUFA	0.000	0.45	0.11	0.23, 0.67	<0.001	0.38	0.08	0.21, 0.54
Cholesterol	0.892	-0.01	0.10	-0.21, 0.19	0.026	0.18	0.08	0.02, 0.33
Thiamine	<0.001	1.13	0.09	0.95, 1.30	<0.001	1.18	0.09	1.01, 1.35
Riboflavin	<0.001	-0.80	0.10	-1.01, -0.60	<0.001	-0.62	0.12	-0.95, -0.39
Niacin equiv.	0.028	-0.29	0.13	-0.55, -0.03	<0.001	-0.49	0.13	-0.74, -0.24
Vitamin B6	0.850	-0.02	0.11	-0.25, 0.20	0.289	0.14	0.13	-0.12, 0.39
Folate	<0.001	0.59	0.13	0.33, 0.84	<0.001	0.61	0.13	0.35, 0.87
Vitamin B12	0.216	0.15	0.12	-0.09, 0.39	0.363	0.11	0.12	-0.13, 0.35
β-carotene	<0.001	0.60	0.11	0.38, 0.82	<0.001	0.53	0.11	0.32, 0.74

Nutrient	Raw				Adjusted			
	Significance (*p*-value)	Unstandardized coefficients (β)	SE	LOA (95% Confidence Interval)	Significance (*p*-value)	Unstandardized coefficients (β)	SE	LOA (95% Confidence Interval)
Vitamin A	<0.001	0.53	0.13	0.28, 0.78	0.001	0.42	0.12	0.18, 0.66
Vitamin C	0.728	-0.04	0.11	-0.26, 0.18	0.266	-0.12	0.10	-0.32, 0.09
Vitamin E	<0.001	0.40	0.11	0.18, 0.62	<0.001	0.44	0.09	0.27, 0.61
Calcium	<0.001	-0.77	0.09	-0.95, -0.60	<0.001	-0.54	0.10	-0.73, -0.35
Iron	0.025	0.26	0.11	0.03, 0.48	0.511	0.09	0.13	-.017, 0.34
Iodine	0.206	0.16	0.13	-0.09, 0.41	<0.001	0.56	0.11	0.34, 0.78
Potassium	0.003	-0.33	0.11	-0.55, -0.12	2.021	0.27	0.13	0.00, 0.54
Magnesium	0.153	0.14	0.10	-0.05, 0.34	<0.001	0.76	0.08	0.60, 0.93
Phosphorus	<0.001	-0.48	0.10	-0.68, -0.27	0.549	-0.07	0.12	-0.30, 0.16
Selenium	<0.001	1.47	0.10	1.28, 1.67	<0.001	1.40	0.10	1.20, 1.60
Zinc	0.208	-0.13	0.10	-0.33, 0.07	0.260	0.13	0.12	-0.10, 0.36

LOA = Limits of agreement; Unstandardized coefficients (β) = slope of bias; Niacin equiv. = Niacin equivalents total, the sum of the percentage of niacin, preformed and niacin equivalent from tryptophan; SAFA = Saturated fatty acid; MUFA = Monounsaturated fatty acid; PUFA = Polyunsaturated fatty acid.

Supplementary Table 2 Regression analysis of nutrient intakes in FFQ1 and FFQ2 (n=319)

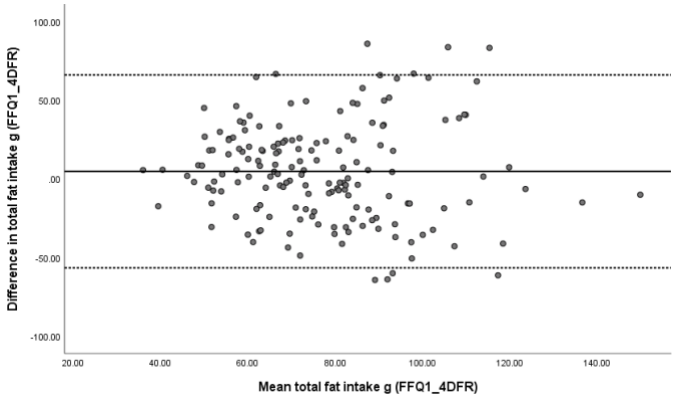
Nutrient	Raw				Adjusted			
	Significance (*p*-value)	Unstandardized coefficients (β)	SE	LOA (95% Confidence Interval)	Significance (*p*-value)	Unstandardized coefficients (β)	SE	LOA (95% Confidence Interval)
Energy	0.235	-0.06	0.05	-0.17, 0.04	-	-	-	-
Protein	0.051	0.11	0.06	0.00, 0.23	0.192	0.07	0.05	-0.04, 0.18
Carbohydrate	0.017	-0.12	0.05	-0.22, -0.02	0.501	0.03	0.04	-0.05, 0.11
Sugars	0.002	-0.16	0.05	-0.27, -0.06	0.484	-0.04	0.05	-0.13, 0.06
Dietary fibre	0.921	-0.00	0.05	-0.10, 0.09	0.040	-0.09	0.04	-0.17, -0.00
Alcohol	<0.001	0.30	0.04	0.22, 0.38	<0.001	-0.30	0.04	-0.38, -0.21
Total fat	0.948	0.00	0.05	-0.10, 0.10	0.561	-0.03	0.04	-0.11, 0.06
SAFA	0.884	0.00	0.05	-0.10, 0.09	0.210	-0.06	0.05	-0.15, 0.03
MUFA	0.884	0.00	0.05	-0.12, 0.10	0.649	0.02	0.05	-0.08, 0.13
PUFA	0.111	0.08	0.05	-0.02, 0.17	0.007	-0.12	0.04	-0.21, -0.04
Cholesterol	0.001	-0.20	0.06	-0.32, -0.08	<0.001	0.27	0.05	0.18, 0.37
Thiamine	0.046	-0.10	0.05	-0.20, -0.00	0.362	-0.05	0.06	-0.16, 0.06
Riboflavin	0.016	-0.13	0.05	-0.23, -0.02	0.628	0.02	0.05	-0.07, 0.12
Niacin equiv.	0.563	-0.03	0.05	-0.13, 0.07	0.815	0.01	0.05	-0.08, 0.10
Vitamin B6	0.367	-0.04	0.04	-0.13, 0.05	0.879	-0.01	0.05	-0.10, 0.08
Folate	0.766	-0.02	0.06	-0.13, 0.10	0.954	-0.00	0.06	-0.11, 0.11
Vitamin B12	<0.001	-0.44	0.07	-0.58, -0.30	<0.001	0.39	0.07	0.25, 0.53
β-carotene	<0.001	0.32	0.06	0.21, 0.44	<0.001	-0.30	0.05	-0.40, -0.18
Vitamin A	<0.001	-0.56	0.08	-0.71, -0.40	<0.001	0.47	0.08	0.31, 0.63
Vitamin C	0.072	-0.10	0.06	-0.07, -0.21	0.944	0.00	0.05	-0.10, 0.11

Nutrient	Raw				Adjusted			
	Significance (*p*-value)	Unstandardized coefficients (β)	SE	LOA (95% Confidence Interval)	Significance (*p*-value)	Unstandardized coefficients (β)	SE	LOA (95% Confidence Interval)
Vitamin E	0.190	-0.06	0.05	-0.16, 0.03)	0.219	-0.05	0.04	-0.13, 0.03
Calcium	0.027	-0.12	0.05	-0.22, -0.01	0.903	0.00	0.05	-0.09, 0.10
Iron	0.568	0.03	0.06	-0.08, 0.14	0.755	0.02	0.06	-0.09, 0.13
Iodine	0.051	-0.11	0.06	-0.21, 0.00	0.043	0.12	0.06	0.00, 0.23
Potassium	0.118	-0.09	0.05	-0.19, 0.02	0.991	0.00	0.05	-0.10, 0.11
Magnesium	0.194	-0.07	0.05	-0.17, 0.03	0.652	-0.02	0.05	-0.11, 0.07
Phosphorus	0.013	-0.13	0.05	-0.23, -0.03	0.621	-0.08	0.17	-0.41, 0.25
Selenium	0.068	0.12	0.06	-0.01, 0.24	0.853	-0.01	0.05	-0.12, 0.10
Zinc	0.263	-0.07	0.06	-0.18, 0.05	0.020	0.03	0.01	0.00, 0.05

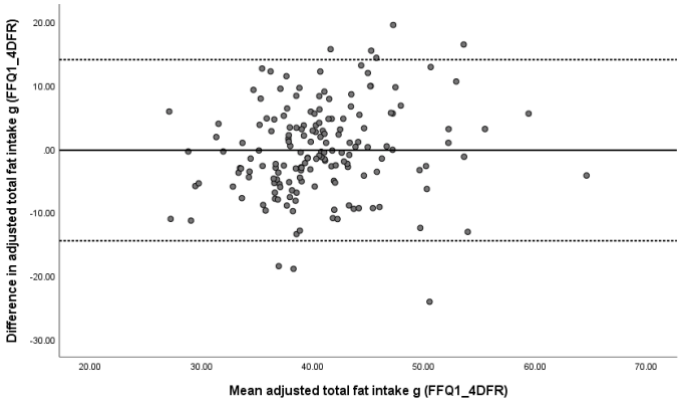
LOA = Limits of agreement; Unstandardized coefficients (β) = slope of bias; Niacin equiv. = Niacin equivalents total, the sum of the percentage of niacin, preformed and niacin equivalent from tryptophan; SAFA = Saturated fatty acid; MUFA = Monounsaturated fatty acid; PUFA = Polyunsaturated fatty acid.

Appendix F: Bland-Altman plots for energy adjusted nutrients and unadjusted nutrients

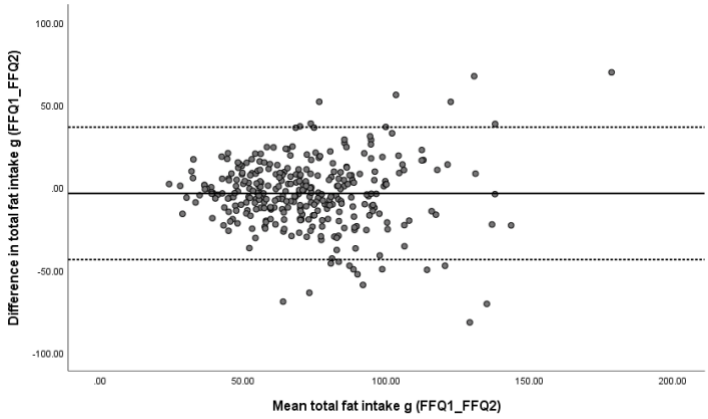
(A)



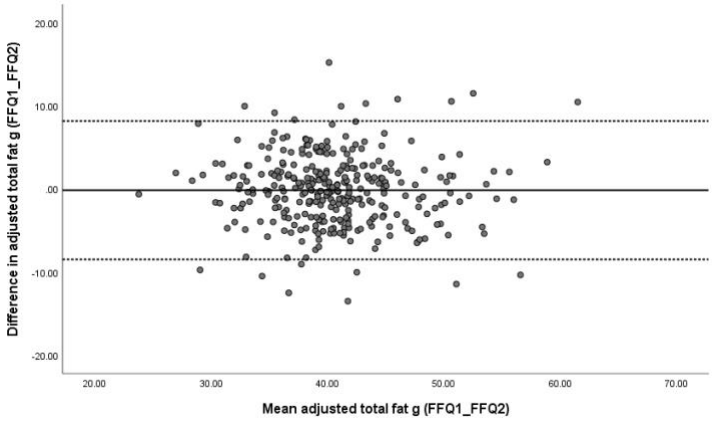
(B)



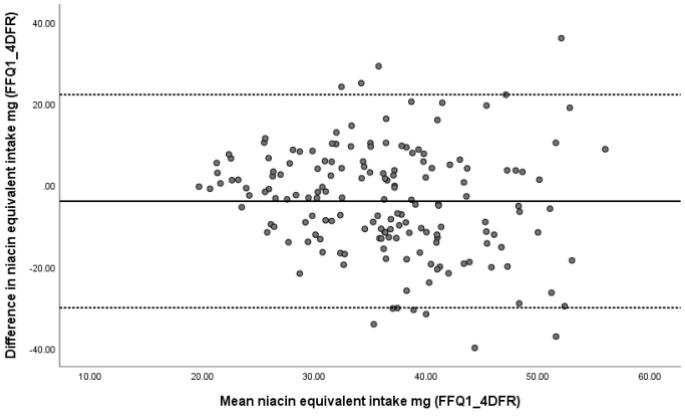
(C)



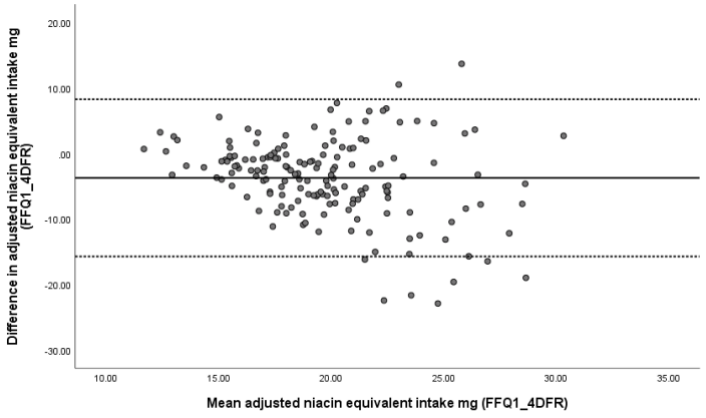
(D)



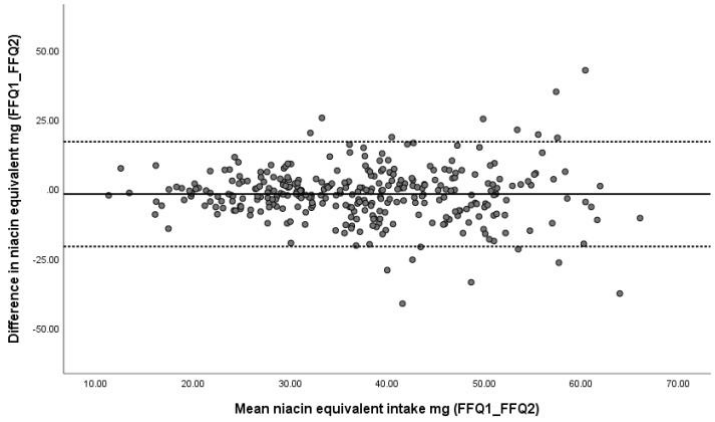
(E)



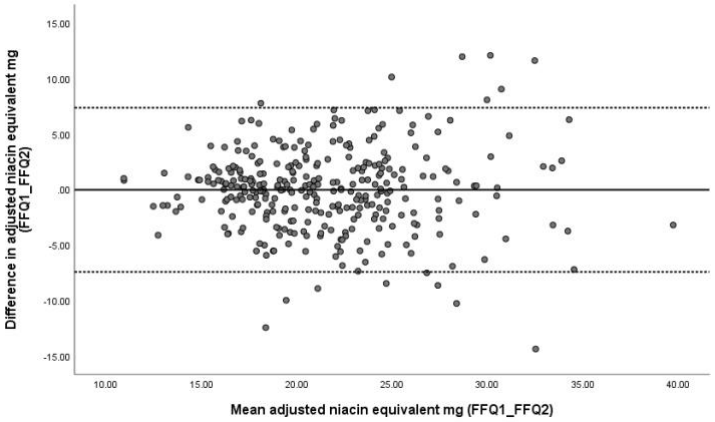
(F)



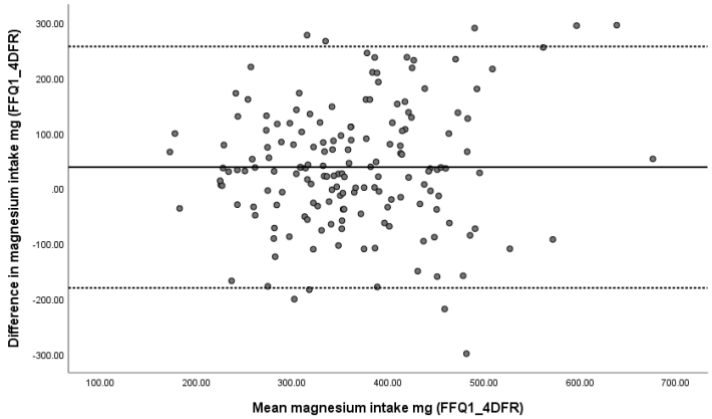
(G)


Difference in niacin equivalent mg (FFQ1_FFQ2)
50.00
25.00
.00
-25.00
-50.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
Mean niacin equivalent intake mg (FFQ1_FFQ2)

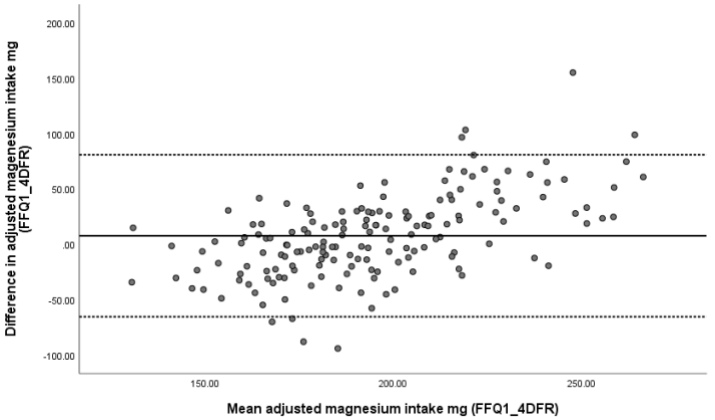
(H)


Difference in adjusted niacin equivalent mg (FFQ1_FFQ2)
15.00
10.00
5.00
.00
-5.00
-10.00
-15.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
Mean adjusted niacin equivalent mg (FFQ1_FFQ2)

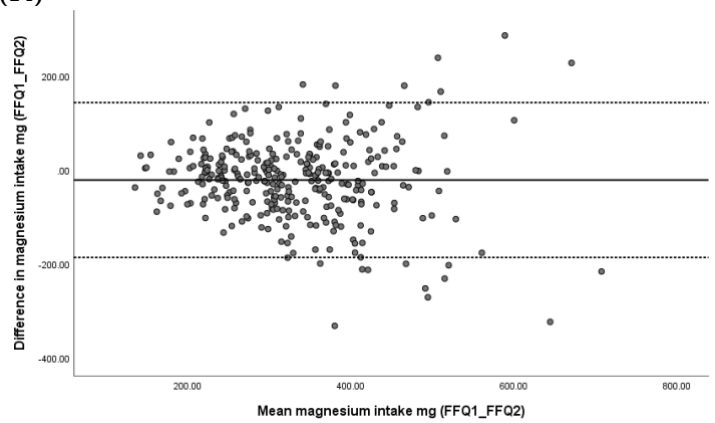
(I)


Difference in magnesium intake mg (FFQ1_4DFR)
300.00
200.00
100.00
.00
-100.00
-200.00
-300.00
100.00
200.00
300.00
400.00
500.00
600.00
700.00
Mean magnesium intake mg (FFQ1_4DFR)

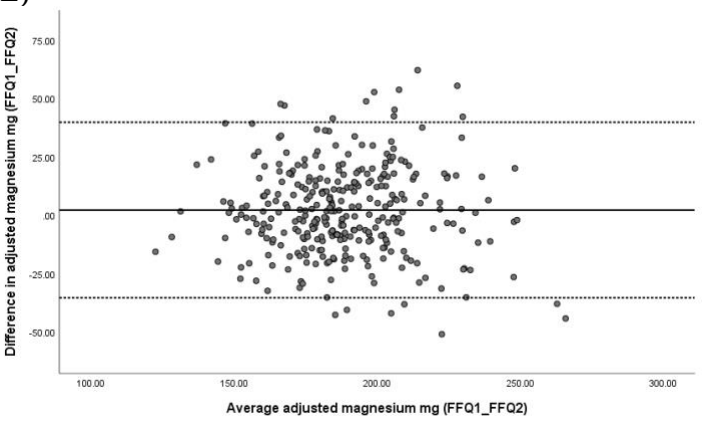
(J)


Difference in adjusted magenesium intake mg (FFQ1_4DFR)
200.00
150.00
100.00
50.00
.00
-50.00
-100.00
150.00
200.00
250.00
Mean adjusted magnesium intake mg (FFQ1_4DFR)

(K)


Difference in magnesium intake mg (FFQ1_FFQ2)
200.00
.00
-200.00
-400.00
200.00
400.00
600.00
800.00
Mean magnesium intake mg (FFQ1_FFQ2)

(L)


Difference in adjusted magnesium mg (FFQ1_FFQ2)
75.00
50.00
25.00
.00
-25.00
-50.00
100.00
150.00
200.00
250.00
300.00
Average adjusted magnesium mg (FFQ1_FFQ2)

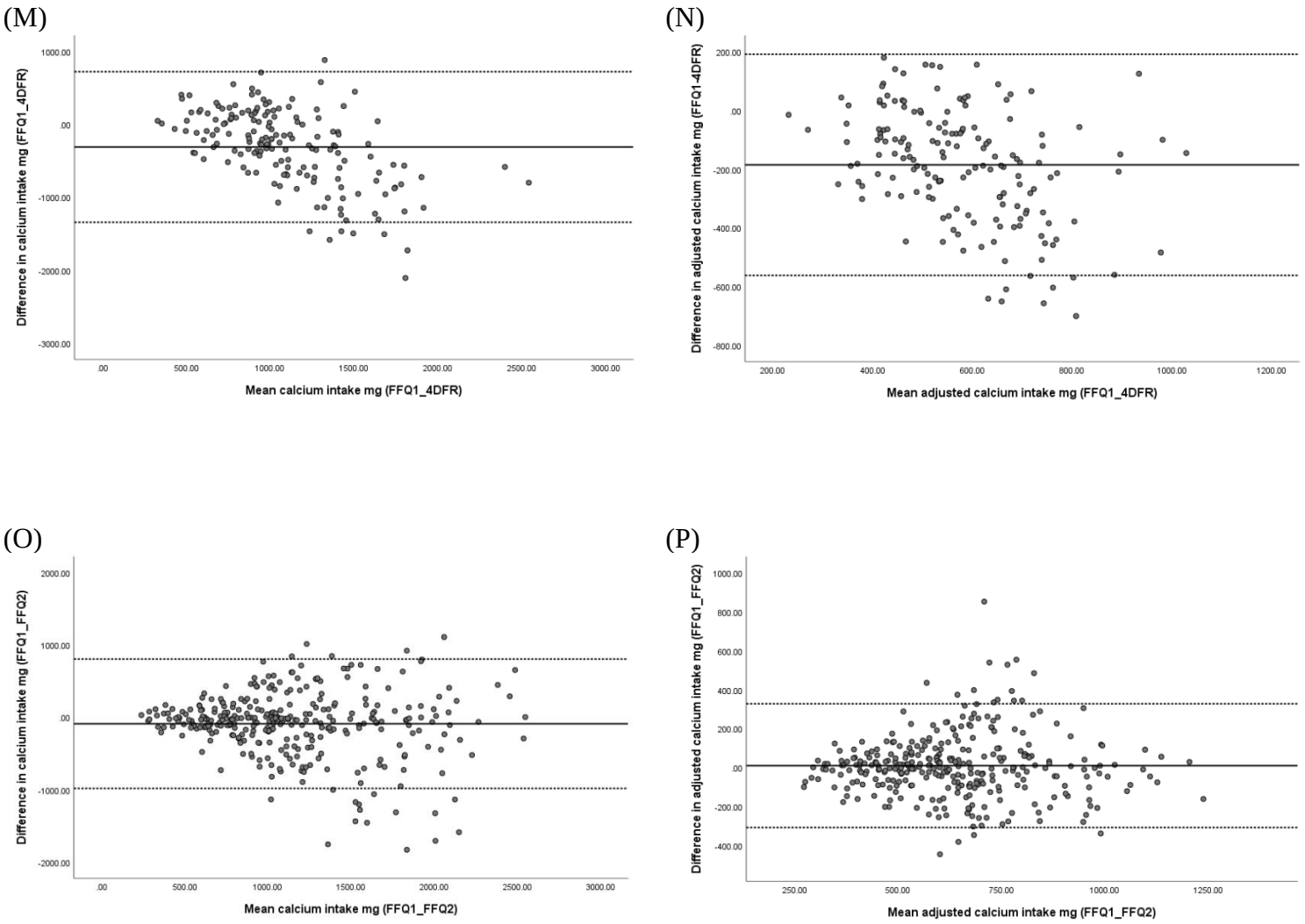


Figure 5.1. Examples of Bland-Altman plots for validity and reproducibility for nutrients. (A) Validity of unadjusted total fat intake. (B) Validity of energy adjusted total fat. (C) Reproducibility of unadjusted total fat. (D) Reproducibility of energy adjusted total fat. (E) Validity of unadjusted niacin. (F) Validity of energy adjusted niacin. (G) Reproducibility of unadjusted niacin. (H) Reproducibility of energy adjusted niacin. (I) Validity of unadjusted magnesium. (J) Validity of energy adjusted magnesium. (K) Reproducibility of unadjusted magnesium. (L) Reproducibility of energy adjusted magnesium. (M) Validity of unadjusted calcium. (N) Validity of energy adjusted calcium. (O) Reproducibility of unadjusted calcium. (P) Reproducibility of energy adjusted calcium. The middle solid line represents the mean difference between the two dietary assessment methods and the dotted line. The dotted lines represent the limits of agreement (mean difference ± 1.96SD). Note: Bland-Altman plots for all energy adjusted and unadjusted nutrients are available on request at Massey University.

School of Sport, Exercise and Nutrition, Massey University, Albany
Contact by email or phone – Angela: angeladawnyu@gmail.com 02108418357; Cathyrn: C.Colon@massey.ac.nz; Kathryn: K.L.Beck@massey.ac.nz

References

AMOUTZOPOULOS, B., STEER, T., ROBERTS, C., CADE, J. E., BOUSHEY, C. J., COLLINS, C. E., TROLLE, E., DE BOER, E. J., ZIAUDDEEN, N., VAN ROSSUM, C., BUURMA, E., COYLE, D. & PAGE, P. 2018. Traditional methods v. new technologies - dilemmas for dietary assessment in large-scale nutrition surveys and studies: a report following an international panel discussion at the 9th International Conference on Diet and Activity Methods (ICDAM9), Brisbane, 3 September 2015. *Journal of nutritional science,* 7**,** e11-e11. Available: 10.1017/jns.2018.4

BANNA, J. C., MCCRORY, M. A., FIALKOWSKI, M. K. & BOUSHEY, C. 2017. Examining Plausibility of Self-Reported Energy Intake Data: Considerations for Method Selection. *Frontiers in nutrition,* 4**,** 45-45. Available: 10.3389/fnut.2017.00045

BARNARD, N. D. 2010. Trends in food availability, 1909–2007. *The American Journal of Clinical Nutrition,* 91**,** 1530S-1536S. Available: 10.3945/ajcn.2010.28701G %J The American Journal of Clinical Nutrition

BAZELMANS, C., MATTHYS, C., DE HENAUW, S., DRAMAIX, M., KORNITZER, M., DE BACKER, G. & LEVÊQUE, A. 2007. Predictors of misreporting in an elderly population: the 'Quality of life after 65' study. *Public Health Nutrition,* 10**,** 185-191. Available: 10.1017/S1368980007246774

BECK, K. L., HOUSTON, Z. L., MCNAUGHTON, S. A. & KRUGER, R. 2018. Development and evaluation of a food frequency questionnaire to assess nutrient intakes of adult women in New Zealand. *Nutrition & Dietetics*. Available: 10.1111/1747-0080.12472

BECK, K. L., KRUGER, R., CONLON, C. A., HEATH, A.-L. M., COAD, J., MATTHYS, C., JONES, B. & STONEHOUSE, W. 2012. The Relative Validity and Reproducibility of an Iron Food Frequency Questionnaire for Identifying Iron-Related Dietary Patterns in Young Women. *Journal of the Academy of Nutrition and Dietetics,* 112**,** 1177-1187. Available: 10.1016/j.jand.2012.05.012

BELL, A. C., SWINBURN, B. A., AMOSA, H., SCRAGG, R. & SHARPE. 1999. Measuring the dietary intake of Samoans living in New Zealand: Comparison of a food frequency questionnaire and a 7 day diet record. *Asia Pacific J Clin Nutr*, 8**,** 149-154.

BLAND, J. M. & ALTMAN, D. G. 1999. Measuring agreement in method comparison studies. *Statisitcal Methods in Medical Research,* 8(2)**,** 135-160. Available: 10.1177/096228029900800204

BLOCK, G. & HARTMAN, A. M. 1989. Issues in reproducibility and validity of dietary studies. *The American Journal of Clinical Nutrition,* 50**,** 1133-1138. Available: 10.1093/ajcn/50.5.1133 %J The American Journal of Clinical Nutrition

BOUCHER, B., COTTERCHIO, M., KREIGER, N., NADALIN, V., BLOCK, T. & BLOCK, G. 2006. Validity and reliability of the Block98 food-frequency questionnaire in a sample of Canadian women. *Public Health Nutrition,* 9**,** 84-93. Available: 10.1079/PHN2005763

CADE, J., THOMPSON, R., BURLEY, V. & WARM, D. 2002. Development, validation and utilisation of food-frequency questionnaires – a review. *Public Health Nutrition,* 5**,** 567-587. Available: 10.1079/PHN2001318

CADE, J. E., BURLEY, V. J., WARM, D. L., THOMPSON, R. L. & MARGETTS, B. M. 2004. Food-frequency questionnaires: a review of their design, validation and utilisation. *Nutrition Research Reviews,* 17**,** 5-22. Available: 10.1079/NRR200370

CARITHERS, T. C., TALEGAWKAR, S. A., ROWSER, M. L., HENRY, O. R., DUBBERT, P. M., BOGLE, M. L., TAYLOR, H. A., JR. & TUCKER, K. L. 2009. Validity and calibration of food frequency questionnaires used with African-American adults in the Jackson Heart Study. *Journal of the American Dietetic Association,* 109**,** 1184-1193. Available: 10.1016/j.jada.2009.04.005

CHERNOFF, R. 2001. Nutrition and Health Promotion in Older Adults. *The Journals of Gerontology: Series A,* 56**,** 47-53. Available: 10.1093/gerona/56.suppl_2.47

CLOVER, E., MILLER, M., BANNERMAN, E. & MAGAREY, A. 2007. Relative validation of a short food frequency questionnaire to assess calcium intake in older adults. *Australian and New Zealand Journal of Public Health,* 31**,** 450-458. Available: doi:10.1111/j.1753-6405.2007.00117.x

COHEN, J. 1968. Weighted kappa: Nominal scale agreement provision for scaled disagreement or partial credit. *Psychological Bulletin,* 70**,** 213-220. Available: 10.1037/h0026256

CORNWALL, J. & DAVEY, J. A. 2004. Impact of Population Ageing in New Zealand on the Demand for Health and Disability Support Services, and Workforce Implications- Background paper prepared for the Ministry of Health. *New Zealand Institute for Research on Ageing (NZiRA) and the Health Services Research Centre (HSRC), Victoria University of Wellington*

CORRENTE, J. E., MARCHIONI, D. M. L. & FISBERG, R. M. 2013. Validation of a FFQ (Food Frequency Questionnaire) for older people. *Journal of Life Science*, 7**,** 878.

DREWNOWSKI, A. & EVANS, W. J. 2001. Nutrition, Physical Activity, and Quality of Life in Older Adults: Summary. *The Journals of Gerontology: Series A,* 56**,** 89-94. Available: 10.1093/gerona/56.suppl_2.89 %J The Journals of Gerontology: Series A

ELDRIDGE, A. L., PIERNAS, C., ILLNER, A.-K., GIBNEY, M. J., GURINOVIĆ, M. A., DE VRIES, J. H. M. & CADE, J. E. 2018. Evaluation of New Technology-Based Tools for Dietary Intake Assessment-An ILSI Europe Dietary Intake and Exposure Task Force Evaluation. *Nutrients,* 11**,** 55. Available: 10.3390/nu11010055

EYSTEINSDOTTIR, T., THORSDOTTIR, I., GUNNARSDOTTIR, I. & STEINGRIMSDOTTIR, L. 2012. Assessing validity of a short food frequency questionnaire on present dietary intake of elderly Icelanders. *Nutrition Journal,* 11**,** 12. Available: 10.1186/1475-2891-11-12

FLETCHER, P. & LYNN, R. 2002. Health of Older People in New Zealand: A Statistical Reference *In:* MINISTRY OF HEALTH. (ed.), Ministry of Health, Wellington

FUKUMOTO, A., ASAKURA, K., MURAKAMI, K., SASAKI, S., OKUBO, H., HIROTA, N., NOTSU, A., TODORIKI, H., MIURA, A., FUKUI, M. & DATE, C. 2013. Within- and between-individual variation in energy and nutrient intake in Japanese adults: effect of age and sex differences on group size and number of records required for adequate dietary assessment. *Journal of epidemiology,* 23**,** 178-186. Available: 10.2188/jea.je20120106

GIBSON, R. S. 2005. Principles of nutritional assessment *In:* GIBSON, R. S. (ed.), *Principles of nutritional assessment.* 2nd ed. New York.

GILSING, A., MAYHEW, A. J., PAYETTE, H., SHATENSTEIN, B., KIRKPATRICK, S. I., AMOG, K., WOLFSON, C., KIRKLAND, S., GRIFFITH, L. E. & RAINA, P. 2018. Validity and Reliability of a Short Diet Questionnaire to Estimate Dietary Intake in Older Adults in a Subsample of the Canadian Longitudinal Study on Aging. *Nutrients,* 10**,** 1522. Available: 10.3390/nu10101522

GOLDBERG, G., BLACK, A., JEBB, S., COLE, T., MURGATROYD, P., COWARD, W. & PRENTICE, A. 1991. Critical evaluation of energy intake data using fundamental principles of energy physiology: Derivation of cut-off limits to identify under-recording. *European journal of clinical nutrition*, 45(12)**,** 569-581.

GREENFIELD, H. & SOUTHGATE, D. A. 2003. *Food composition data: production, management, and use.* Elsevier Science Publishers and Food and Agriculture Org. Available: 10.1007/978-1-4615-3544-7

HAFTENBERGER, M., HEUER, T., HEIDEMANN, C., KUBE, F., KREMS, C. & MENSINK, G. B. 2010. Relative validation of a food frequency questionnaire for national health and nutrition monitoring. *Nutrition Journal,* 9**,** 36. Available: 10.1186/1475-2891-9-36

HICKSON, M. 2006. Malnutrition and ageing. *Postgraduate medical journal,* 82**,** 2-8. Available: 10.1136/pgmj.2005.037564

HOFFMAN, R. 2017. Micronutrient deficiencies in the elderly - could ready meals be part of the solution? *Journal of nutritional science,* 6**,** e2-e2. Available: 10.1017/jns.2016.42

HOPKINS, WG., MARSHALL, SW., BATTERHAM, AM., & HANIN, J. 2009. Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Medicine & Science in Sports & Exercise*, 41(1)**,** 3-12. Available: 10.1249/MSS.0b013e31818cb278

HORWATH, C. C. 1993. Validity of a short food frequency questionnaire for estimating nutrient intake in elderly people. *British Journal of Nutrition,* 70**,** 3-14. Available: 10.1079/BJN19930100

HUGHES, D. B., HARRIS, S. S., KRALL, E. A. & DALLAL, G. E. 1997. Effect of calcium and vitamin D supplementation on bone, density in men and women 65 years of age or older. *New England Journal of Medicine,* 337**,** 670-676. Available: 10.1056/nejm199709043371003

INGRAM, M. A., KRUGER, R., STONEHOUSE, W., RUSSELL, K. G. & MEYER, B. J. 2012. The New Zealand PUFA Semiquantitative Food Frequency Questionnaire Is a Valid and Reliable Tool to Assess PUFA Intakes in Healthy New Zealand Adults. *The Journal of Nutrition,* 142**,** 1968-1974. Available: 10.3945/jn.112.162313

JIA, S. X., CRAIG, L., AUCOTT, L., MILNE, A. & MCNEILL, G. 2009. Repeatability and validity of a food frequency questionnaire in free-living older people in relation to cognitive function. *The journal of nutrition, health & aging,* 12**,** 735-41. Available: 10.1007/BF03028622

KIPNIS, V., FREEDMAN, L. S., BROWN, C. C., HARTMAN, A. M., SCHATZKIN, A. & WACHOLDER, S. 1997. Effect of Measurement Error on Energy-Adjustment Models in Nutritional Epidemiology. *American Journal of Epidemiology,* 146**,** 842-855. Available: 10.1093/oxfordjournals.aje.a009202 %J American Journal of Epidemiology

KLIPSTEIN-GROBUSCH, K., BREEIJEN, J. D., GOLDBOHM, R., GELEIJNSE1, J., HOFMAN, A., GROBBEE, D. & WITTEMAN, J. 1998. Dietary assessment in the elderly: validation of a semiquantitative food frequency questionnaire. *European Journal of Clinical Nutrition,* 1998**,** 588-96.

LI, K., WANG, X., LI, D., CHEN, Y., ZHAO, L., LIU, X., GUO, Y., SHEN, J., LIN, X., DENG, J., ZHOU, R. & DENG, H. 2018. The good, the bad, and the ugly of calcium supplementation: a review of calcium intake on human health. *Clinical interventions in aging,* 13**,** 2443-2452. Available: 10.2147/CIA.S157523

LI, Z. & HEBER, D. 2012. Sarcopenic obesity in the elderly and strategies for weight management. *Nutrition Reviews,* 70**,** 57-64. Available: 10.1111/j.1753-4887.2011.00453.x

LIPS, P. 2001. Vitamin D deficiency and secondary hyperparathyroidism in the elderly: Consequences for bone loss and fractures and therapeutic implications. *Endocrine Reviews,* 22**,** 477-501. Available: 10.1210/er.22.4.477

MACDIARMID, J. & BLUNDELL, J. 1998. Assessing dietary intake: Who, what and why of under-reporting. *Nutrition Research Reviews,* 11**,** 231-253. Available: 10.1079/NRR19980017

MACDONELL, S. O., MILLER, J. C., HARPER, M. J., WATERS, D. L. & HOUGHTON, L. A. 2016. Vitamin D status and its predictors in New Zealand aged-care residents eligible for a government-funded universal vitamin D supplementation programme. *Public Health Nutrition,* 19**,** 3349-3360. Available: 10.1017/S1368980016001683

MALEKAHMADI, M., NAEINI, A., SHAB-BIDAR, S., FEIZI, A. & DJAZAYERY, A. 2016. Development, validity, and reliability of a food frequency questionnaire for antioxidants in elderly Iranian people. 21**,** 14-14. Available: 10.4103/1735-1995.178753

MARES-PERLMAN, J. A., KLEIN, B. E. K., KLEIN, R., RITTER, L. L., FISHER, M. R. & FREUDENHEIM, J. L. 1993. A Diet History Questionnaire Ranks Nutrient Intakes in Middle-Aged and Older Men and Women Similarly to Multiple Food Records. *The Journal of Nutrition,* 123**,** 489-501. Available: 10.1093/jn/123.3.489 %J The Journal of Nutrition

MARGETTS, B. M. & NELSON, M. 1997. *Design Concepts in Nutritional Epidemiology*, Oxford University Press.

MARGETTS, B. M. & NELSON, M. 1997. Design concepts in nutritional epidemiology.

MARTIN BLAND, J. & ALTMAN, D. 1986. Statistical metods for assessing agreement between two methods of clinical measurement. *The Lancet,* 327**,** 307-310. Available: https://doi.org/10.1016/S0140-6736(86)90837-8

MASSON, L. F., MCNEILL, G., TOMANY, J. O., SIMPSON, J. A., PEACE, H. S., WEI, L., GRUBB, D. A. & BOLTON-SMITH, C. 2003. Statistical approaches for assessing the relative validity of a food-frequency questionnaire: use of correlation coefficients and the kappa statistic. *Public Health Nutrition,* 6**,** 313-321. Available: 10.1079/PHN2002429

MCNEILL, G., MASSON, L., MACDONALD, H., HAGGARTY, P., MACDIARMID, J., CRAIG, L. & KYLE, J. 2008. Food frequency questionnaires vs diet diaries. *International Journal of Epidemiology,* 38**,** 884-884. Available: 10.1093/ije/dyn237

MERTENS, E., KUIJSTEN, A., GELEIJNSE, J. M., BOSHUIZEN, H. C., FESKENS, E. J. M. & VAN'T VEER, P. 2019. FFQ versus repeated 24-h recalls for estimating diet-related environmental impact. *Nutrition journal,* 18**,** 2-2. Available: 10.1186/s12937-018-0425-z

METCALF, P., SWINBURN, B., SCRAGG, R. & DRYSON, E. 1997. Reproducibility and validity of a food frequency questionnaire in European and polynesian New Zealanders. *Ethnicity & Health,* 2**,** 297-308. Available: 10.1080/13557858.1997.9961838

MINISTRY OF HEALTH. 2016. Health Loss in New Zealand 1990–2013: A report from the New Zealand Burden of Diseases, Injuries and Risk Factors Study. Wellington: Ministry of Health

MINISTRY OF HEALTH. 2002. Health of Older People in New Zealand: A Statistical Reference. Wellington: Ministry of Health

MINISTRY OF HEALTH. 2017. Annual Data Explorer 2016/17: New Zealand Health Survey [Data File].

MINISTRY OF HEALTH. 2018. Measuring weight. Available: https://www.health.govt.nz/your-health/healthy-living/food-activity-and-sleep/healthy-weight/measuring-weight

MILLER, J. C., MACDONELL, S. O., GRAY, A. R., REID, M. R., BARR, D. J., THOMSON, C. D. & HOUGHTON, L. A. 2016. Iodine Status of New Zealand Elderly Residents in Long-Term Residential Care. *Nutrients,* 8**,** 445. Available: 10.3390/nu8080445

MILLER, M., YEO, Y. C., KHOR, M. J., CLOVER, E. & MAGAREY, A. 2010. Repeatability of a Short Food Frequency Questionnaire to Assess Calcium Intake in Older Australians. *Journal of Aging Research*. 2010. Available: 10.4061/2010/905056

MILTE, C. M. & MCNAUGHTON, S. A. 2016. Dietary patterns and successful ageing: a systematic review. *European journal of nutrition,* 55**,** 423-450. Available: 10.1007/s00394-015-1123-7

MITCHELL, C. J., MILAN, A. M., MITCHELL, S. M., ZENG, N. N., RAMZAN, F., SHARMA, P., KNOWLES, S. O., ROY, N. C., SJODIN, A., WAGNER, K. H. & CAMERON-SMITH, D. 2017. The effects of dietary protein intake on appendicular lean mass and muscle function in elderly men: a 10-wk randomized controlled trial. *American Journal of Clinical Nutrition,* 106**,** 1375-1383. Available: 10.3945/ajcn.117.160325

MORRIS, M. C., TANGNEY, C. C., BIENIAS, J. L., EVANS, D. A. & WILSON, R. S. 2003. Validity and Reproducibility of a Food Frequency Questionnaire by Cognition in an Older Biracial Sample. *American Journal of Epidemiology,* 158**,** 1213-1217. Available: 10.1093/aje/kwg290 %J American Journal of Epidemiology

MUMME, K. D., VON HURST, P. R., CONLON, C. A., JONES, B., HASKELL-RAMSAY, C. F., STONEHOUSE, W., HEATH, A.-L. M., COAD, J. & BECK, K. L. J. B. P. H. 2019. Study protocol: associations between dietary patterns, cognitive function and metabolic syndrome in older adults – a cross-sectional study. *BMC Public Health*, 19**,** 535. Available: 10.1186/s12889-019-6900-4

NELSON, M., ATKINSON, M. & MEYER, J. 1997. *Food Portion Sizes : A Photographic Atlas.* London, MAFF Publications.

NEW ZEALAND STATISTICS. 2014. 2013 Cencus QuickStats About culture and identity.

NORTH, S. M., WHAM, C. A., TEH, R., MOYES, S. A., ROLLESTON, A. & KERSE, N. 2018. High nutrition risk related to dietary intake is associated with an increased risk of hospitalisation and mortality for older Māori: LiLACS NZ. *Australian and New Zealand Journal of Public Health,* 42**,** 375-381. Available: 10.1111/1753-6405.12793

OTAGO UNIVERSITY & MINISTRY OF HEALTH. 2011. A Focus on Nutrition: Key findings of the 2008/09 New Zealand Adult Nutrition Survey. Wellington: Ministry of Health.

RHEE, J. J., SAMPSON, L., CHO, E., HUGHES, M. D., HU, F. B. & WILLETT, W. C. 2015. Comparison of methods to account for implausible reporting of energy intake in epidemiologic studies. *American journal of epidemiology,* 181**,** 225-233. Available: 10.1093/aje/kwu308

RUSH, E. C. & YAN, M. R. 2017. Evolution not Revolution: Nutrition and Obesity. *Nutrients,* 9**,** 519. Available: 10.3390/nu9050519

SALLÉ, A., RYAN, M. & RITZ, P. 2006. Underreporting of Food Intake in Obese Diabetic and Nondiabetic Patients. 29**,** 2726-2727. Available: 10.2337/dc06-1582 %J Diabetes Care

SAM, C. H. Y., SKEAFF, S. & SKIDMORE, P. M. L. 2014. A comprehensive FFQ developed for use in New Zealand adults: reliability and validity for nutrient intakes. *Public Health Nutrition,* 17**,** 287-296. Available: 10.1017/S1368980012005058

SAWAYA, A. L., TUCKER, K., TSAY, R., WILLETT, W., SALTZMAN, E., DALLAL, G. E. & ROBERTS, S. B. 1996. Evaluation of four methods for determining energy intake in young and older women: comparison with doubly labeled water measurements of total energy expenditure. *The American Journal of Clinical Nutrition,* 63**,** 491-499. Available: 10.1093/ajcn/63.4.491 %J The American Journal of Clinical Nutrition

SCHOFIELD, W. 1985. Predicting basal metabolic rate, new standards and review of previous work. *Clinical nutrition,* 39**,** 5-41.

SCHULZE, M. B., MARTÍNEZ-GONZÁLEZ, M. A., FUNG, T. T., LICHTENSTEIN, A. H. & FOROUHI, N. G. 2018. Food based dietary patterns and chronic disease prevention. *bmj*, 361**,** k2396. Available: 10.1136/bmj.k2396 %J BMJ

SCOTT, D., BLIZZARD, L., FELL, J., GILES, G. & JONES, G. 2010. Associations Between Dietary Nutrient Intake and Muscle Mass and Strength in Community-Dwelling Older Adults: The Tasmanian Older Adult Cohort Study. *Journal of the American Geriatrics Society,* 58**,** 2129-2134. Available: 10.1111/j.1532-5415.2010.03147.x

SHARPE, H. & BRADBURY, S. 2015. Understanding excess body weight: New Zealand Health Survey.

SHARPE, S., PAGE, N., GAMBLE, G. & SHARPE, C. 1993. Validation of a food frequency questionnaire for use in cardiovascular risk factor studies in New Zealand. PROCEEDINGS-NUTRITION SOCIETY OF NEW ZEALAND (vol. 18, 90-90). NUTRITION SOCIETY OF NEW ZEALAND.

SHIM, J.-S., OH, K. & KIM, H. C. 2014. Dietary assessment methods in epidemiologic studies. *Epidemiology and health,* 36**,** e2014009-e2014009. Available: 10.4178/epih/e2014009

SMITH, W., MITCHELL, P., REAY, E. M., WEBB, K. & HARVEY, P. W. J. 1998. Validity and reproducibility of a self-administered food frequency questionnaire in older people. *Australian and New Zealand journal of public health,* 22(4)**,** 456-463. Available: 10.1111/j.1467-842X.1998.tb01414.x

STEFANOGIANNIS, N., LAWES, C. M. M., TURLEY, M., TOBIAS, M., VANDER HOORN, S., MHURCHU, C. N. & RODGERS, A. 2005. Nutrition and the burden of disease in New Zealand: 1997–2011. *Public Health Nutrition,* 8**,** 395-401. Available: 10.1079/PHN2004694

STEWART, A., MARFELL-JONES, M., OLDS, T. & DE RIDDER, J. 2011. *International Standards for Anthropometric Assessment*.

STRAM, D. O., HANKIN, J. H., WILKENS, L. R., PIKE, M. C., MONROE, K. R., PARK, S., HENDERSON, B. E., NOMURA, A. M. Y., EARLE, M. E., NAGAMINE, F. S. & KOLONEL, L. N. 2000. Calibration of the Dietary Questionnaire for a Multiethnic Cohort in Hawaii and Los Angeles. *American Journal of Epidemiology,* 151**,** 358-370. Available: 10.1093/oxfordjournals.aje.a010214 %J American Journal of Epidemiology

STRAM, D. O., LONGNECKER, M. P., SHAMES, L., KOLONEL, L. N., WILKENS, L. R., PIKE, M. C. & HENDERSON, B. E. 1995. Cost-Efficient Design of a Diet Validation Study. *American Journal of Epidemiology,* 142**,** 353-362. Available: 10.1093/oxfordjournals.aje.a117641 %J American Journal of Epidemiology

THE NEW ZEALND INSTITUTE FOR PLANT AND FOOD RESEARCH LIMITED. 2019. New Zealand Food Composition Database 2019 New Zealand FOODfiles 2018 Manual. The New Zealand Institute for Plant and Food Research Limited and Ministry of Health

TER BORG, S., VERLAAN, S., HEMSWORTH, J., MIJNARENDS, D. M., SCHOLS, J. M., LUIKING, Y. C. & DE GROOT, L. C. 2015. Micronutrient intakes and potential inadequacies of community-dwelling older adults: a systematic review. *British Journal of Nutrition,* 113**,** 1195-1206.

THOMPSON, F., SUBAR, A. F. & 2001. Dietary Assessment Methodology. *Nutrition in the Prevention and Treatment of Disease* 4ed.: Elsevier Inc. Available: 10.1016/B978-012193155-1/50003-9

THOMPSON, F. E. & BYERS, T. 1994. Dietary Assessment Resource Manual. *The Journal of Nutrition,* 124**,** 2245s-2317s. Available: 10.1093/jn/124.suppl_11.2245s %J The Journal of Nutrition

UNITED NATIONS. DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS, POPULATION DIVISION. 2017. World Population Ageing 2017 - Highlights. New York, United States: United Nations.

VAN DRONKELAAR, C., VAN VELZEN, A., ABDELRAZEK, M., VAN DER STEEN, A., WEIJS, P. J. M. & TIELAND, M. 2018. Minerals and Sarcopenia; The Role of Calcium, Iron, Magnesium, Phosphorus, Potassium, Selenium, Sodium, and Zinc on Muscle Mass, Muscle Strength, and Physical Performance in Older Adults: A Systematic Review. *Journal of the American Medical Directors Association,* 19**,** 6-11.e3. Available: https://doi.org/10.1016/j.jamda.2017.05.026

VISSER, M., DE GROOT, L. C. P. G. M., DEURENBERG, P. & VAN STAVEREN, W. A. 1995. Validation of dietary history method in a group of elderly women using measurements of total energy expenditure. *British Journal of Nutrition,* 74**,** 775-785. Available: 10.1079/BJN19950005

WATANABE, D., NANRI, H., YOSHIDA, T., YAMAGUCHI, M., SUGITA, M., NOZAWA, Y., OKABE, Y., ITOI, A., GOTO, C., YAMADA, Y., ISHIKAWA-TAKATA, K., KOBAYASHI, H., KIMURA, M. & KYOTO-KAMEOKA STUDY GROUP, K.-K. S. 2019. Validation of Energy and Nutrition Intake in Japanese Elderly Individuals Estimated Based on a Short Food Frequency Questionnaire Compared against a 7-day Dietary Record: The Kyoto-Kameoka Study. *Nutrients,* 11**,** 688. Available: 10.3390/nu11030688

WHAM, C., BAGGETT, F., TEH, R., MOYES, S., KĒPA, M., CONNOLLY, M., JATRANA, S. & KERSE, N. 2015. Dietary protein intake may reduce hospitalisation due to infection in Māori of advanced age: LiLACS NZ. *Australian and New Zealand Journal of Public Health,* 39, 390-395. Available: 10.1111/1753-6405.12406

WATSON, J., LEE, M. & GARCIA-CASAL, M. N. 2018. Consequences of Inadequate Intakes of Vitamin A, Vitamin B(12), Vitamin D, Calcium, Iron, and Folate in Older Persons. *Current geriatrics reports,* 7**,** 103-113. Available: 10.1007/s13670-018-0241-5

WHITTON, C., NICHOLSON, S. K., ROBERTS, C., PRYNNE, C. J., POT, G. K., OLSON, A., FITT, E., COLE, D., TEUCHER, B., BATES, B., HENDERSON, H., PIGOTT, S., DEVERILL, C., SWAN, G. & STEPHEN, A. M. 2011. National Diet and Nutrition Survey: UK food consumption and nutrient intakes from the first year of the rolling programme and comparisons with previous surveys. *The British journal of nutrition,* 106**,** 1899-1914. Available: 10.1017/S0007114511002340

WILLETT, W. 2001. Commentary: Dietary diaries versus food frequency questionnaires—a case of undigestible data. *International Journal of Epidemiology,* 30**,** 317-319. Available: 10.1093/ije/30.2.317

WILLETT, W. 2012. Nutritional epidemiology. *Oxford University Press*

WILLETT, W. C., HOWE, G. R. & KUSHI, L. H. 1997. Adjustment for total energy intake in epidemiologic studies. *The American Journal of Clinical Nutrition,* 65**,** 1220S-1228S. Available: 10.1093/ajcn/65.4.1220S %J The American Journal of Clinical Nutrition

WILLETT, W. C., SAMPSON, L., STAMPFER, M. J., ROSNER, B., BAIN, C., WITSCHI, J., HENNEKENS, C. H. & SPEIZER, F. E. 1985. Reproducibility and validity of a semiquantitative food frequency questionnaire. *American Journal of Epidemiology,* 122**,** 51-65. Available: 10.1093/oxfordjournals.aje.a114086

WILSON, P. & HORWATH, C. 1996. Validation of a short food frequency questionnaire for assessment of dietary calcium intake in women. *European journal of clinical nutrition,* 50**,** 220-228.

YANG, L. J., WU, G. H., YANG, Y. L., WU, Y. H., ZHANG, L., WANG, M. H., MO, L. Y., XUE, G., WANG, C. Z. & WENG, X. F. 2019. Nutrition, Physical Exercise, and the Prevalence of Sarcopenia in

Elderly Residents in Nursing Homes in China. *Medical Science Monitor,* 25**,** 4390-4399. Available: 10.12659/msm.914031

ZIAUDDEEN, N., ALMIRON-ROIG, E., PENNEY, T. L., NICHOLSON, S., KIRK, S. F. L. & PAGE, P. 2017. Eating at Food Outlets and "On the Go" Is Associated with Less Healthy Food Choices in Adults: Cross-Sectional Data from the UK National Diet and Nutrition Survey Rolling Programme (2008–2014). *Nutrients,* 9**,** 1315.