Validation of a food frequency questionnaire to assess nutrient intakes in women participating in the PRedictors linking Obesity and gut MIcrobiomE (PROMIsE) Study

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Abstract

Background: Diet is a modifiable risk factor for a range of chronic diseases. Food frequency questionnaires (FFQ) are commonly used in epidemiological studies to investigate this relationship due to their ease of administration, low cost and ability to assess nutrient intake over an extended period of time. Like all dietary assessment tools FFQ's are not free of error and need to be validated for use in their intended population. There is currently no FFQ that has been independently validated for use in the Pacific and New Zealand (NZ) European women in New Zealand.

Aim To validate a semi-quantitative food frequency questionnaire in 18-45-year-old pre-menopausal adult NZ European and Pacific women participating in the PROMIsE study, living in the greater Auckland area.

Methods Participants included 287 premenopausal women living in New Zealand of NZ European (n=161) and Pacific (n=126) ethnicity. Women completed an FFQ (NZWFFQ) designed to assess the dietary intake of 31 nutrients over the previous month and a five-day estimated food record (5d-FR). Relative validity was assessed by comparing the nutrient intakes of the NZWFFQ and 5d-FR using Wilcoxon signed rank test, Spearman's correlation coefficients, cross-classification, weighted kappa statistic and Bland-Altman analysis. Validity was evaluated for crude and energy adjusted data for the total group and separately for NZ European and Pacific ethnicity.

Results The nutrient intake of the NZWFFQ was higher than the 5d-FR overall for all nutrients (range: 6%-113% difference) except iodine (-16%). Correlation coefficients ranged from 0.07 for iodine in the unadjusted total group to 0.63 for alcohol. The highest energy correlation coefficients were for energy adjusted NZ European data (0.17-0.73) and were lowest for the unadjusted Pacific data (-0.02-0.47). Classification into same and adjacent quartiles of intake, and gross misclassification into opposite quartiles, were respectively 77.5% and 5.41% for the total group, 81% and 3.6% for the NZ European group, and 71.2% and 7.6% for the Pacific group for energy adjusted data. The weighted kappa showed slight to moderate agreement for the total group (0.12-0.47), slight to moderate agreement (0.16-0.54) for NZ European, and slight to fair agreement (-0.10-0.28) for the Pacific group. Bland-Altman analysis showed wide limits of agreement for nutrients in each group, with wider limits of agreement and larger mean differences for the Pacific group.

Conclusion: The NZWFFQ gives good validity for ranking NZ European women by nutrient intake however did not compare well for ranking Pacific women by nutrient intake. As most

nutrients were overestimated by the NZWFFQ it is not a suitable tool to use for estimating absolute nutrient intake.

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List of abbreviations

24HR	Twenty-four hour recall
5d-FR	5-day estimated food record
BMI	Body mass index
BMR	Basal metabolic rate
CI	Confidence intervals
CVD	Cardiovascular disease
DLW	Doubly labelled water
e.g.	Example
EXPLORE	Examining the Predictors Linking Obesity Related Elements
EFR	Estimated food record
FAO	Food and Agricultural Organization of the United Nations
FFQ	Food frequency questionnaire
κ	Weighted Kappa statistic
LoA	Limits of Agreement
MUFA	Monounsaturated fat
MOH	Ministry of Health
n	Number
NCDs	Non-communicable Diseases
NZ	New Zealand
NZ European	New Zealand European
NZWFFQ	New Zealand Women's Food Frequency Questionnaire
$Pr(a)^2$	Relative observed agreement
$Pr(e)^2$	Hypothetical probability of chance agreement
PROMIsE	PRedictors linking Obesity and gut MIcrobiomE
PUFA	Polyunsaturated fat
r	Spearman's correlation coefficient
SFA	Saturated fat
SD	Standard deviation
WFR	Weighed food record
WHO	World Health Organisation

Chapter 1: Introduction

Diet is a major risk factor for a range of chronic diseases (World Health Organisation [WHO], 2003 Willett, 2012; Willett et al., 2006). Some chronic diseases such as coronary artery disease, stroke, diabetes and some cancers can be prevented with realistic modifications in diet and lifestyle (Willett et al., 2006). Recommendations from The World Health Organisation suggest limiting sodium to less than 1.7g per day could prevent 38% of deaths from stroke or coronary heart disease (WHO, 2003); a further 1.7 million deaths per year are attributed to low fruit and vegetable intake with adequate fruit and vegetable consumption shown to reduce the risk for cardiovascular disease and some cancers (WHO, 2003). The increasing evidence supporting the contribution of diet in the aetiology of health and disease has encouraged the rigorous measurement of dietary intake to understand the relationship between chronic disease and diet with the ultimate goal to improve human health (Lee & Nieman, 2007; Willett, 1998).

To measure diet, a range of dietary assessment tools have been developed and evaluated. The food frequency questionnaires (FFQ), are one tool that have often been the preferred choice worldwide in epidemiological studies for their ease of administration, low cost and their ability to assess both food and nutrient intake over an extended period of time (Cade, Burley, Warm, Thompson, & Margetts, 2004; Food and Agriculture Organisation of the United Nations [FAO], 2018). Using FFQ data, diet-disease relationships with coronary heart disease (Hu & Willett, 2002) and type-2 diabetes (Fung, Schulze, Manson, Willett, & Hu, 2004; Hu, van Dam, & Liu, 2001) have previously been shown. However, some diet-disease associations that have been detected with dietary biomarkers have been found to be undetectable by FFQs including the association between breast cancer and diet in women (Fowke et al., 2003). Weak associations made using FFQs have minimised their ability to detect true diet-disease relationships, thereby limiting their usefulness (Kristal, Peters, & Potter, 2005). Like all dietary assessment tools, FFQs, are not free of error, and therefore, must be validated for use in their intended population before any conclusions can be drawn about how eating impacts on health (Margetts & Nelson, 1997; Molag et al., 2007).

Within New Zealand (NZ), there is a disparity in the incidence of these chronic diseases such as diabetes, ischaemic heart disease and stroke between Pacific people and the rest of the NZ population. Pacific people are more than twice as likely to have Type 2 diabetes (T2DM) (Ministry of Health [MOH], 2017b). Type 2 Diabetes is preventable and is

associated with an increase in body fat (Hu, Manson, et al., 2001). Pacific adults are also more likely, to be obese when compared to the national population. Compared to the national average of 32%, 69% of Pacific adults were obese in the 2016/17 National Health survey and only 8.4% of Pacific women were classified as having a healthy weight (BMI: 18.5-24.9kg/m^2) compared to 35% of NZ European women (MOH, 2017b).

Obesity in young to middle aged adults is also of concern (Ministry of Health [MOH], 2016). This is of particular importance as it is a time of child bearing for many women. Obesity during pregnancy may further impact on to future generations. Research has shown, obese pregnant mothers are more likely to have heart disease and hypertension later in life and the risk the child has of developing T2DM and obesity is increased (Eriksson, Sandboge, Salonen, Kajantie, & Osmond, 2014; Leddy, Power, & Schulkin, 2008). Nutrients are also important in women in this stage of life, including iodine and folic acid during pregnancy. Adequate folic acid levels are important to reduce the risk of neural tube defects (NTDs) during pregnancy, however only 27% of women of child-bearing age in NZ had folate levels associated with a low risk of NTDs (University of Otago & Ministry of Health, 2011). Nutrient needs of iron are also higher in this age group to replace losses during menstruation. Prevalence of iron deficiency and iron deficiency anaemia is highest for females aged 15-18 years and 31-50 years (15.5% and 18.1% respectively) compared to 6.2% in the total population (University of Otago & Ministry of Health, 2011). Inadequate intake of calcium is even more likely with 68% of 19-30 year old women and 56% of 31-50 year old women deficient in calcium (University of Otago & Ministry of Health, 2011).

To my knowledge here are only five FFQ's previously validated for use in the New Zealand population (Beck, Houston, McNaughton, & Kruger, 2018; Bell, Swinburn, Amosa, Scragg, & Sharpe, 1999; Bolch, 1994; Metcalf, Swinburn, Scragg, & Dryson, 1997; Sam, Skeaff, & Skidmore, 2012; Sharpe, Page, Gamble, & Sharpe, 1993). Few have validated FFQs specific to Pacific populations living in New Zealand (Bell et al., 1999; Metcalf et al., 1997) and only one of these FFQs, the New Zealand Women's Food Frequency Questionnaire (NZWFFQ), have recently been validated for use specifically in the female population (Beck et al., 2018). This highlights the need for any FFQ to be validated independently for use in different gender and ethnicity groups living in the NZ population.

The NZWFFQ previously validated for use in the general population of women (Beck et al., 2018), is used in the current study and therefore requires validation in this large population of

NZ European and Pacific premenopausal women living in NZ. The PRedictors linking Obesity and the gut MIcrobiomE (PROMIsE) study, is a cross-sectional study examining the relationship between the gut microbiome and predictors of obesity. This sub-study seeks to validate the nutrient intake as measured by the NZWFFQ of the total sample, as well as New Zealand European and Pacific premenopausal women independently.

Study Aims

To validate a semi-quantitative food frequency questionnaire in 18-45-year-old pre-menopausal adult NZ European and Pacific women participating in the PROMIsE study, living in the greater Auckland area of New Zealand.

Objectives

1. To determine and compare the energy and nutrient intakes of premenopausal Pacific and New Zealand European women participating in the PROMIsE study using the NZ Women's Food Frequency Questionnaire (NZWFFQ) and a 5-day estimated food record.

2. To validate the NZWFFQ against the 5-day estimated food record in all premenopausal Pacific and New Zealand European women participating in the PROMIsE study.
    2.1 To determine if the NZWFFQ is a valid tool to assess the nutrient intakes of premenopausal adult New Zealand European women.
    2.2 To determine if the NZWFFQ is a valid tool to assess the nutrient intakes of premenopausal adult Pacific women.

1.2 Structure of the thesis

Chapter 1 introduces the study and outlines aims and objectives. **Chapter 2** reviews the literature on dietary assessment methods and validation of dietary assessment tools. **Chapter 3** presents the results of the validation study presented as a manuscript for publication in the *Asia Pacific Journal of Clinical Nutrition.* **Chapter 4** includes a brief overview of the study findings, provides strengths and limitations and provides final recommendations for future research.

1.3 Contributions of Researchers

Table 1.1 Researchers' contributions to the study

Researcher	Contribution
Beatrice Drury	Primary author of this thesis and assisted in aspects of this study including: data collection and data entry for the PROMIsE study, data and statistical analysis, interpretation of results, and preparing the final manuscript.
A/Prof Rozanne Kruger Academic supervisor	Concept and research design of the PROMIsE study and ethical application, supervised NZWFFQ and 5d-DR data entry and analysis. Supervision of the entire research process. Assisted with editing, finalising and approval of this thesis.
Dr Marilize Richter Academic co-supervisor	Supervised data entry and analysis of the PROMIsE study. Advisor for statistical analysis.
Prof Bernhard Breier	Lead investigator of the PROMIsE study. Concept and research design of the PROMIsE study, ethical application.
Jo Dawson and Nikki Renall	Dietitians responsible for dietary review interviews and checking of food records, planning and implementation of the PROMIsE study
Sophie Kindleysides, Niamh Brennan, Moana Manukia, Sherina Holland, Owen Mugridge	Planning, recruitment, screening and execution of the PROMIsE study; data collection including: anthropometry, questionnaires, food record education
Laura Mickleson, Ashleigh Jackson, Shivon Singh, Amelia Franklin, Alexandra Thompson, Anishka Ram, Sunna Jacobsen	Data collection and entry including: 5d-DR and BIA

Chapter 2: Literature review

2.1 Introduction

This chapter reviews the literature on the topic of dietary assessment and validation of dietary assessment methods between November 2017 to July 2018. Relevant literature was found using the following electronic databases: Discover, PubMed, Web of Science and Google Scholar using search terms including: Dietary assessment, food frequency questionnaire, FFQ. Search terms were used in conjunction with 'AND' or 'OR' and included further search terms: validation, NZ/New Zealand, NZ European, Pacific, women, premenopausal women, review, statistical methods. Included search results were limited to full-text English scholarly journal articles, library books and ebooks.

2.2 Dietary Intake and Health in NZ European and Pacific Women

Non-communicable diseases (NCDs) are a major concern in New Zealand and account for 89% of all deaths (WHO, 2003). These diseases including cardiovascular diseases, T2DM, and some cancers contribute to the long term conditions that are the most significant cause of health loss in New Zealand from ill health, disability and mortality (Ministry of Health [MOH], 2017a). While the rates of mortality from some of these diseases such as cardiovascular disease are declining, the disparity between Pacific and NZ European ethnic groups has not (MOH, 2017a). Pacific and Maori have the slowest rates of decline in cardiovascular diseases compared to any other group (MOH, 2017a) in New Zealand and 12.5% of Pacific women are living with T2DM, while only 4.4% of European women were affected (MOH, 2017b).

One of the modifiable risk factors common to all NCDs is poor diet. In New Zealand 9.4% of health loss is estimated to be contributed from poor diet including high intake of sugar, fat and red meat and low consumption of fruit and vegetables (MOH, 2017a). Inadequate intake of fruits and vegetables is also more prevalent in the Pacific population with only 31% reaching the suggested five or more servings per day verses 42% in the European New Zealand population (MOH, 2017b). Poor diet, such as a high intake of energy-dense micronutrient poor foods, and a high intake of sugar-sweetened beverages have also been linked to excess weight gain (WHO, 2003). Obesity is an increasing concern in New Zealand with the obesity rate increasing from 27% in 2006/7 to 32% in 2017/18 (Ministry of

Health [MOH], Ministry of Health, 2017b; 2018). The likelihood of being over-weight or obese is more common in both Pacific and NZ European populations than being at a normal weight, with 91% of Pacific women and 64% of European women being overweight or obese (MOH, 2017b).

Poor intake of some nutrients is also of concern in New Zealand, with women at greater risk of certain nutrient deficiencies such as iron, calcium and selenium (MOH, 2016). The most recent national nutrition survey found the risk of iron deficiency had increased in women over the age of 15 by 4% from 1997 to 2008/09, and over half the female adult population was also deficient in calcium and selenium (73% and 58% respectively) (MOH, 2016). Although folate status was generally adequate, only 27% of women had folate levels high enough to put their foetus at a low risk of neural tube defects (MOH, 2017b). As over half the number of pregnancies in New Zealand are unplanned (52%) (Hohmann-Marriott, 2018), this presents a concern for women of childbearing age.

2.2 Dietary assessment methods

'There is not and probably never will be, a method that can estimate intake without error' (Beaton, 1994). The choice of dietary assessment method and validation method must be chosen with thorough consideration. The following section discusses each method with corresponding strengths and limitations.

Dietary assessment tools are used to estimate dietary intake of an individual or a population and can be categorised as prospective and retrospective methods. Prospective methods include the estimated or weighed food records, that report dietary intake as actually consumed over specified days, compared to retrospective methods, including the 24-hour diet recall, diet history and food frequency questionnaires, reporting dietary data as perceived to be consumed in the immediate, recent, or distant past (Cameron & Staveren, 1988; Willett, 1998).

Selection between these categories, and the appropriate choice of a specific dietary assessment tool depends on the purpose of the study, the required accuracy of the chosen method, resources available and the population being studied. Careful consideration of the characteristics of the intended study population is also necessary, including level of literacy, ability to accurately recall from memory, age, culture, ethnic group, health status and ability

to communicate (Cade et al., 2004; Lee & Nieman, 2007).

The strengths and weaknesses of each individual tool should be considered when choosing a methodology, as all dietary assessment tools present with measurement error. Therefore, the strengths and limitations of each method should be considered and balanced against all other study considerations. For example, choosing a tool that obtains more precision, may be used at the expense of a high participation rate (Cade, Thompson, Burley, & Warm, 2002; Cameron & Staveren, 1988). Understanding each assessment method and its corresponding strengths and weaknesses aids in accurately selecting the most appropriate assessment tool to demonstrate diet-disease relationships in research. It further allows the reader to identify and draw their own conclusions on the study outcomes (Lee & Nieman, 2007).

A summary of the considerations and comparison between retrospective and prospective dietary assessment methods are listed in Table 2.1.

Table 2.1 Dietary intake assessment tools (Cade et al., 2002; Cameron & Staveren, 1988; FAO, 2018; Gibson, 2005; Lee & Nieman, 2007; Willett, 1998, 2012)

Method	Actual or usual intake	Requires literacy	Participant burden	Cost	Strengths	Limitations
24-hour Recall	Actual or usual	No	Low	Low	▪ Quick and easy to administer by a trained interviewer ▪ Low respondent burden ▪ Can provide detailed information on specific foods ▪ Short-term memory only required ▪ open ended questions	▪ Relies on memory ▪ Misreporting / underreporting ▪ Inaccuracy of portion sizes due to errors in conceptualization and memory ▪ Labour intensive data entry ▪ Underestimation of dressings, sauces and beverages can lead to low estimates of energy intake ▪ Daily variation in diet limits precision of estimating usual intake especially with 24-hour recall method ▪ Respondent must have ability to describe their own diet
Food record	Actual	Yes	High	Low	▪ Does not depend on memory ▪ Provides detailed data on intake and eating habits ▪ Reasonably valid for up to 5 days ▪ Can be representative of usual intake if record obtained for more than one day ▪ Uses open ended questions	▪ High participant response burden ▪ Participants must be highly motivated. ▪ Time consuming ▪ Process of keeping record may distort food habits of participant ▪ High cost, time and labour for analysis ▪ Daily variation in diet limits precision of usual intake when insufficient number of days recorded ▪ Underreporting ▪ Inaccuracy of portion sizes due to errors in conceptualization
Diet history	Usual	No	Low	Low	▪ Eating behaviour is not manipulated ▪ Open ended questions ▪ Can collect diet over a long period of time ▪ Can obtain portion sizes and frequency of consumption ▪ Can obtain usual food consumption	▪ Interviewer bias ▪ Inaccuracy of portion sizes due to errors in conceptualisation and memory ▪ Errors in reporting frequency ▪ Time consuming interview process ▪ Requires interviewers to be highly trained ▪ Difficult and expensive to code

Method	Actual or usual intake	Requires literacy	Participant burden	Cost	Strengths	Limitations
						▪ Misreporting, particularly overestimation of nutrient intake and underreporting of irregular eating patterns ▪ Requires cooperative respondent ▪ Respondent must have ability to describe their own diet and regular eating habits
Food frequency questionnaire	Usual	No -Interview-administered Yes – Self-administered	Low	Low	▪ Quick and simple to administer compared to other questionnaires ▪ Useful to identify usual food and nutrient intakes over a long period of time ▪ Can be self-administered ▪ Can capture portion size estimates and obtain information on cooking and preparation methods ▪ Can be completed online using a survey tool which accurately records responses ▪ Ease of administration ▪ Basis of design can be on large population data ▪ Can obtain frequency of intake from daily, weekly, monthly or yearly	▪ May not represent usual foods or portion sizes of participant ▪ The food list does not cover all foods consumed by the participant and can lead to underreporting ▪ Respondent must have ability to describe their own diet ▪ Misinterpretation of questions may lead to omission of food items if self-administered ▪ If multiple foods are grouped within single listings, intake data can be compromised ▪ Considerable amount of time and resources required for development and validation of questionnaire ▪ Low level of accuracy in estimating usual diet or nutrient intake ▪ Closed ended questions ▪ Longer questionnaires can be tedious to complete while short can lack comprehensiveness ▪ Not suitable in populations that have distinctly different dietary patterns ▪ Limited to accuracy of food composition tables and must be updated to include more food and food products continually available to the marketplace each year.

24-hour Recall

The food recall is often used in clinical settings and requires a trained interviewer such as a dietitian or nutritionist who asks the subjects to recall the exact intake of food and drink over the previous 24 hours (FAO, 2018). This method assesses the actual intake of participants over one day or multiple non-consecutive days.

The trained interviewer collects dietary information in an open-ended format and probes any further detail to obtain preparation methods and other foods the participant may have missed (FAO, 2018; Willett, 2012). Accuracy of results is variable among groups with different ages, genders, attention, mood and intelligence levels. Quantifying portion sizes is another error associated with dependence on memory during the data collection process, however conception and perception of portion sizes is equally difficult for participants (Willett, 2012). Measuring tools such as household cups, spoons and bowls, or photographs of these items, are often used by researchers to help estimate portion sizes (Willett, 2012). The 24-hour recall method is often well received by participants as they are easy and quick to administer, and effort required by the respondent is minimal. However, participants may adjust or withhold some information; often over-reporting foods considered more 'healthful' or 'desired' such as expensive cuts of meat, while underreporting information regarding consumption of 'unhealthful' foods, alcoholic beverages or binge eating (Lee & Nieman, 2007; Willett, 2012; Yunsheng et al., 2009).

Another major limitation is the ability to measure the usual intake of an individual, as a wide range in intra-individual variation in food intake exists over a single day's diet. To minimise this, food recalls may be repeated with three, four, five or seven days for optimal estimation of energy intake and with some recalls repeated over the year to account for seasonal variation in dietary intake. (Gibson, 2005; Lee & Nieman, 2007; Yunsheng et al., 2009).

Repeated recalls have been used previously in the New Zealand Ministry of Health (MOH) nutritional surveys and are widely used internationally including in the Australian National Nutrition Survey (Australian Bureau of Statistics, 2014). The 2008/09 MOH National Nutrition Survey for NZ used a second 24-hour recall in a sub-sample of the participants within a month of the first 24-hour recall to account for intra-individual variation (University of Otago & Ministry of Health, 2011) due to their low cost and low burden on the

participant (Australian Bureau of Statistics, 2014; University of Otago & Ministry of Health, 2011).

Food records

The food record is a prospective method similar to that of diet recalls, where food consumed and amounts of each food are identified and recorded over the required timeframe, usually between 1 and 7 days. The more days recorded, the more representative of usual intake of the respondent (Gibson, 2005; Lee & Nieman, 2007; Ortega, Pérez-Rodrigo, & López-Sobaler, 2015). Food records require the individual to write down food consumed at the time of consumption to minimise reliance on memory. However, the time and effort from the process of recording, increases participant burden and fatigue. Some participants may begin to complete their record retrospectively and therefore limit the accuracy of the method (Ortega et al., 2015). Therefore, the food record requires a cooperative and highly motivated respondent. However, the longer the length of recording period can lead even the most motivated respondents to alter their diet to simplify the process of recording (Lee & Nieman, 2007; Zaki, Bulgiba, Ismail, & Ismail, 2012). On the other hand, the more days recorded, helps to identify foods consumed less often and will better reflect usual intake. To optimise the data quality while minimising participant burden, an ideal range of 3 to 7 days of recording is recommended. Administering a record on non-consecutive days can also help improve representativeness of the diet, as some foods such as leftovers may be consumed on consecutive days (Ortega et al., 2015).

Food records can be administered as either estimated or weighed food records. Both variations use open ended questions to extract detailed description of food intake required for the research (Willett, 2012). However, weighed food records differ from estimated food records as they use food scales to measure each food item rather than household measures such as measuring cups, teaspoons, glasses and bowls that are then used by researchers to quantify each measure (Gibson, 2005; Lee & Nieman, 2007). While food records are considered the gold standard for measuring dietary intake, a systematic literature review of misreporting energy and micronutrient intakes of food records (Poslusna, Ruprich, de Vries, Jakubikova, & van't Veer, 2009) has shown that both weighed and estimated food records result in an underreporting of energy intake, ranging between 11.9 - 44% in estimated weighed food records and between 14.3 - 38.5% in weighed food records. Therefore, the

weighed food record, due to its higher level of accuracy, is the most precise method available to measure usual intake (Gibson, 2005; Henríquez-Sánchez et al., 2009; Willett, 1998). Although, there was no significant difference between methods (Poslusna, Ruprich, de Vries, Jakubikova, & van't Veer, 2009). The level of specificity of food and preparation practices is unlimited and therefore, the food record method is useful 'to estimate intakes in culturally diverse populations representing wide ranges of foods and eating habits (Willett, 2012).

Food records are regarded as the 'gold standard' measurement of dietary intake (Ortega et al., 2015). However, when deciding on the most appropriate tool to measure 'usual' dietary intake in epidemiological studies, food records are not practical due to their significant burden on participants, personal and economic resources, and are often an underrepresentation of usual intake. Therefore, other methods may need to be considered, such as food frequency questionnaires (Macedo-Ojeda et al., 2013; Sam et al., 2012; Willett, 1998).

Dietary History

Diet histories are used to estimate the individual's total food intake and usual meal pattern over a specific time frame, usually a month or year (Cameron and Staveren, 1988). This technique requires three parts: a 24-hour record, 3-day food diary and an FFQ to collect food usually consumed (Morán Fagúndez et al., 2015; Shim, Oh, & Kim, 2014). The 24-hour recall is generally used by a trained interviewer to collect the general information about the health habits of the participant, questioning the usual eating pattern of the respondent and estimating amount consumed using household measures such as cups and bowls. Information is then checked for completeness by asking the respondent about their dietary patterns using a food frequency questionnaire to check usual intake and a 3-day estimated food record to check actual intake (Morán Fagúndez et al., 2015). Diet histories are time consuming, taking around 90 minutes to complete and require a highly skilled interviewer and thus, are not regularly used in epidemiological studies (Shim et al., 2014).

Food frequency questionnaires

Food frequency questionnaires (FFQ) are one of the key tools widely used in nutritional epidemiological studies. An FFQ is able to measure average long-term food and nutrient intake and are a preferred dietary assessment tool due to their low cost and ease of use (Gibson, 2005).

An FFQ provides a limited list of food items, that contain foods that are major sources of the dietary component under investigation. The respondent is required to report how frequently each food item in the list is consumed either per day, week, month or year. An FFQ can be used to assess energy intake and/or particular nutrients, or food groups of interest, however the use of a specific number of questions limits the questionnaire from obtaining the high level of detail other dietary assessment methods may be able to obtain and for some individuals, estimation of portion size may be difficult (Cade et al., 2004; Lee & Nieman, 2007; Willett, 1998). Estimation of portion sizes can be cognitively challenging for individuals when reporting foods previously consumed and especially when participants are required to recall frequency of portion size (Cade et al., 2002)

2.3 Design Characteristics of Food Frequency Questionnaires

Types of Questionnaires

Questionnaires include simple or non-quantitative, semi-quantitative or quantitative versions that are based on the degree of description and quantification of portion size estimates. Non-quantitative solely ask about frequency of food consumption. The semi-quantitative FFQ use a closed question format asking frequency of set portion sizes in addition to the frequency of consumption of the particular food; and the quantitative FFQ queries the amount of food consumption and description of the portion size usually consumed in an open ended format (Lee & Nieman, 2007; Shim et al., 2014). Semi-quantitative questionnaires have been the preferred method adopted in epidemiological studies, as they reduce the participant difficulties of estimating own portion sizes previously consumed nd improve quality of data by employing multiple answer choices for portion size (Shim et al., 2014).

Common FFQ designs include the Willet (Willett et al., 1985), Subar and Thompson (Subar et al., 2001), and Block questionnaire (Block et al., 1986). A study comparing the three questionnaires, showed that all three performed similarly after adjusting for energy (Lee & Nieman, 2007).

New FFQ's can be developed or existing FFQ's can be modified, however each questionnaire should be assessed prior to its use in the target population for reliability and validity (Cade et al., 2004; Cade et al., 2002). Modifying an existing questionnaire may be more time and cost efficient however, an FFQ developed previously, may be out of date and unreliable to assess validity in the same population if used a few years on. For example, it may exclude some new food items commonly consumed that were not available when the original FFQ was developed (Cade et al., 2002; Sam et al., 2012). Cade et al. (2002) reported that newly designed FFQ's compared to existing FFQ's had a higher correlation for some nutrients such as energy and fat (0.41 vs 0.44 and 0.52 vs 0.49 respectively), although the overall agreement did not appear to decline between new and adapted questionnaires.

The Food List

The food list in an FFQ cannot be infinite (FAO, 2018). One major error in FFQ's is that its success to capture usual intake is confined to a fixed list of foods, due to the feasibility of including all types of different foods and food products, brands and preparation practices (FAO, 2018). Foods included in a food list are based on whether the study seeks to measure specific foods or nutrients or the overall dietary intake. Foods included in the list must reflect this objective by being eaten relatively often by a reasonable number of the target population to contribute to the absolute intake of the population or to detect differences between individuals (Cade et al., 2002; Willett, 2012).

Study Population

Food frequency questionnaires, like all other dietary assessment tools, come with associated limitations as discussed in Table 2.1. Food choice among individuals is highly variable across different cultural backgrounds, age groups, and physiological statuses, and therefore each FFQ must be designed specifically for its target population (Cade et al., 2004; Cade et al., 2002).

The study target population must be clearly defined, and special care must be taken when the study is aimed at particular groups such as that of cultural groups within a population due to differences in comprehension, cultural taboos, portion size and the range of food patterns (Margetts & Nelson, 1997).

Cultural differences, including cultural awareness, sensitivity and appropriateness need to be recognised to develop a culturally appropriate FFQ (Teufel, 1997). As how one interprets and answers a question depends on how they perceive reality and this depends on their cultural background. Like a lens on a camera, people with similar cultural backgrounds share a similar cultural lens, where their interpretation and perceptions on reality are similar (Teufel, 1997). If an FFQ is developed with the designer's cultural background differing from the respondents, the questions asked will be filtered through a different cultural lens and therefore, the respondent's interpretation of questions on the FFQ may differ from the designers. Without the recognition of the respondents culture when developing an FFQ, miscommunication of interpretation of questions would increase and therefore, this would reduce the overall validity of the FFQ (Teufel, 1997). For instance, the FFQ lists specific foods and asks the participant if they eat them, therefore, if some common foods are excluded in a questionnaire aimed at cultural groups with unique dietary habits, the dietary energy and corresponding nutrients may be underestimated (Lee & Nieman, 2007).

Administration Method

FFQ's may be either interviewer of self-administered. Self-administered questionnaires are most popular as they require fewer interviewer resources. However, a review by Cade et al. (2002) found interviewer administered FFQ's had higher correlation coefficients between reference measures than self-administered FFQ's for fat (0.55 vs. 0.50) and energy (0.55 vs 0.46), respectively. Participant errors and incomplete answers of self-administered FFQ's may limit their accuracy. However, providing an opportunity for clarification to correct any responses may be useful to overcome the limitations associated with self-administered FFQ's and can improve agreement (Cade et al., 2002).

2.4 Measurement errors in dietary assessment

Errors in dietary assessment arise through a number of measurement errors including both random and systematic, that reduce precision and may result in misleading diet-disease conclusions (FAO, 2018; Kipnis et al., 2003; Margetts & Nelson, 1997; Trabulsi & Schoeller, 2001). Random errors may arise from writing or processing mistakes across all participants and all days of recording. These errors can be reduced by increasing the number of measurements. Systematic errors can affect the design, analysis and interpretation of studies. They may be specific to the participant, food or interviewer. Measurement errors that affect validity are systematic and may result in the over- or under-estimation of associations. Sources of error in FFQ's may include food composition tables, food coding reporting error, variation in diet across time and seasons, reporting incorrect frequency or portion size estimation, participant memory lapses, modified eating pattern of participants and respondent bias (FAO, 2018; Kipnis et al., 2003). The following section discusses misreporting, one of the major errors in dietary assessment.

Misreporting of data

Self-reporting tools including FFQ's, food records and 24h-recalls are known to contain systematic error that include both over- and underreporting of dietary intake. Misreporting of dietary assessment tools varies between the method used and subject characteristics, including gender, BMI, ethnicity, and socio-economic group (Livingstone & Black, 2003; Park et al., 2018; Poslusna et al., 2009). Over-reporters tend to be younger, leaner and are more likely to want to increase their body weight, while under-reporters are more likely to be older, have a higher BMI and wanting to reduce their body weight (Johansson, Solvoll, Bjørneboe, & Drevon, 1998).

Under-reporting of energy and certain nutrients, including protein, potassium and sodium, have been correlated with an increase in BMI (Bland & Altman, 1986; Livingstone & Black, 2003; Park et al., 2018), although can still occur in normal weight participants (Park et al., 2018). A systematic literature review by Poslusna et al. (2009) of 24-hour recall and food record methods found a significant difference in misreporting between men and women using estimated food records; a median of 18.5% of men compared to 32.5% of women were classified as under-reporters (Poslusna et al., 2009). However, it is unclear whether men under-report to a lesser degree than women or if the higher energy requirements of men

reduces the number of men falling below a single cut-off and men and women therefore, underreport to the same extent (Poslusna et al., 2009). Other participant characteristics including income and a lower education level, social desirability, body image, restrained eating and depression have been hypothesised to increase under-reporting of dietary energy intake (Horner et al., 2002).

Under-reporting

Under-reporting, including under-recording and under-eating, have consistently been reported in dietary assessment studies using 24-h recalls and food records. Under-reporting of energy intake varied between 11.9 to 44% in those using estimated food records and 14.3 to 38.5% in those using weighed food records in (Poslusna et al., 2009). A recent study comparing dietary assessment methods against biomarkers, found that FFQ's under-reported absolute energy, protein and sodium intakes 1.5-3 times more than self-reported dietary intakes from a 24-hour recall and 4-day record (Park et al., 2018).

Many studies have evaluated under-reporting in energy intake while few studies have compared under-reporting of intake of nutrients (Poslusna et al., 2009). Of those that have, energy yielding nutrients had lower absolute intakes of each nutrient in participants found to report low energy than non-low energy respondents. Some nutrients including iron, calcium and vitamin C were also lower in low energy reporters (Poslusna et al., 2009). Those most prone to misreporting are also more likely to be misclassified in quantiles of intake (Black & Cole, 2001).

Over-reporting

Over-reporting, although less prevalent than under-reporting, is also observed in some studies. Food frequency questionnaires tend to over-estimate intake of energy, energy yielding nutrients and vegetables. Some food groups, such as fruits and vegetables contain a longer list of food items. Furthermore, as foods are often grouped into similar categories in FFQ's, larger groupings, can lead to over-reporting as reporting of combined frequencies can be difficult for some foods and mixed dishes. As many of these food items may be consumed regularly, this may easily lead to over-estimation of intake in terms of either frequency or portion size, and thus over-reporting on an FFQ. Cross-check questions, such as *'On average, how many servings of vegetables do you eat per day?'* may be used to correct for

misreporting of these food groups (Cade et al., 2002). Misreporting in an FFQ due to a subject's perception of portion size may be minimised with the use of food photographs or household measures. However, there is still a tendency for over and under estimation in some foods including fruits and vegetables (Margetts & Nelson, 1997; Poslusna et al., 2009b).

Adjusting for misreporting

Removing under or over-reporters to correct for misreporting may introduce bias into the data. Many studies have used energy adjustment to correct for misreporting of energy intake and reduce correlated errors. Energy adjustment focuses on the composition of the pattern of the diet and may be adjusted using the residual or nutrient density-method (Kipnis et al., 2003). The residual method uses linear regression to make the nutrient amounts independent from the energy intake (EI), while the nutrient density method uses the nutrient absolute amounts and divided by the energy intake. However, in this method energy adjusted nutrients are still correlated with the energy intake in this method, and should therefore not be used when studies are looking for diet-disease associations (Poslusna et al., 2009). Identifying the degree of misreporting can additionally be carried out by validating studies using methods such as the doubly labelled water technique and the Goldberg cut-off as described in the section below.

2.5 Validation

'Nutrition researchers must be able to measure food and nutrient intake with accuracy and precision before drawing conclusions about how health and risk for disease are influenced by what we eat' (Lee & Nieman, 2007).

Validation, refers to the adequacy at which the tool used to measure diet is true and accurate of what it intended to measure (Margetts & Nelson, 1997). Validation ensures any outcome measure is not falsely linked to dietary factors, diseases or disease-related markers, if information from the dietary assessment tool is incorrect (Cade et al., 2004).

To ensure validity, the dietary assessment method of choice must represent a valid reflection of the situation in the relevant population and time. True validity also must use a dietary measurement that measures the exposure with no misclassification of outcome. This requires both internal and external validity. Internal validity refers to the results only being valid for the specific group being studied and requires no bias in the collection, analysis and

interpretation of the data. Internal validity is less difficult to achieve than external validity which refers to the generalisability of the study findings, where to be externally valid the results must be valid for anyone rather than just the specific group being studied (Gibson, 2005; Margetts & Nelson, 1997).

True validity assumes that there is an accurate measure of dietary intake to compare to. However, often this is not possible as it would require absolute validity where absolute validity is measured by assessing the actual food intake during the study and either before or after the study to be compared. This method is time consuming and in many cases can be impractical as it would require collecting the free-living respondents self-selected diet for a period of months and therefore this validity is limited to studies with small sample sizes (Gibson, 2005; Masson et al., 2003). The alternative method is relative validity, where a 'test' method is compared against a 'reference' method that, although it may be imperfect, is considered to be more accurate than the test method. Both test and reference method should use the same subjects, and the choice of reference method ideally should be independent of true intake and error in the FFQ (Gibson, 2005; Kipnis et al., 2003; Masson et al., 2003). Relative validity is designed to 'assess those parameters which are needed to correct measures on association for measurement error for given increments of intake' (Margetts & Nelson, 1997) rather than estimate all sources of measurement error. If the test dietary assessment method gives the same results as the reference measure then the test method provides a valid measure of true exposure (Margetts & Nelson, 1997) and the results may then be used to evaluate associations between nutrient intake and risk of disease (Willett, 1998). However, some common widespread limitations across methods such as misreporting of energy intake, may result in better agreement between dietary methods than is the truth.

A range of methods can be used to determine the misreporting of dietary assessment. Energy expenditure is commonly measured using basal metabolic rate (BMR), doubly labelled water (DLW) is used to assess energy intake and a range of urinary biomarkers such as urinary nitrogen excretion to measure protein intake (Poslusna et al., 2009). The gold standard technique, DLW is one of the most widely used techniques as it is independent of error in self-reported intake and has shown to be accurate to 1%. It is used to measure energy expenditure, equivalent to energy intake in free-living individuals by the production of carbon dioxide. However, due to the high cost and complexity of technology, the DLW technique is not often used in large scale studies (Johnson, 2002; Trabulsi & Schoeller,

2001). Alternatively, the Goldberg cut-off is often applied to identify misreporting as expressed by EI as multiples of BMR and compared to energy expenditure (EE). Those subjects that present with values over or above the Goldberg range given, did not provide a valid measure of energy obtained by chance (Black & Cole, 2001).

2.6 Design criteria for validation studies

Both the test and reference methods must have a variety of similarities within their design to be validated between groups. These are discussed next.

Reference tool

The choice of reference tool must reflect a compromise between cost, ease of administration and time with accuracy (Margetts & Nelson, 1997). A systematic review of food frequency questionnaire validation studies conducted by Cade (2004), found that other dietary assessment methods were the choice of validation tool in 75% of studies. Other validation tools typically used included biomarkers (19%) and doubly labelled water or energy expenditure studies (12%). Table 2.2 highlights common validation instruments and their strengths and limitations.

The choice of other dietary assessment methods such as diet records have most commonly been the method of choice for validation, and although there is no perfectly accurate dietary assessment tool, a superior dietary assessment tool should be used to compare where errors of each method are uncorrelated to one another to avoid inaccurate estimates of validity. Therefore, selection depends on the validity of the reference measure itself and careful selection of a reference dietary assessment tool is required to minimise false diet-disease correlations (Margetts & Nelson, 1997).

The widespread limitations of dietary assessment have led to the increase in popularity in using biomarkers to overcome errors as an external independent marker of dietary intake to provide relative validity (Gibson, 2005). To be used in validation, biomarkers that are usually components of body fluids or tissues, must respond to the amount of a certain nutrient of interest consumed and respond in a dose-dependent manner (Gibson, 2005). Some biomarkers are directly reflected by dietary intake e.g. urinary nitrogen, sodium

and potassium while some other specific nutrients can only discriminate between extremes of nutrient intake and therefore, are not well reflected by dietary intake and will not provide a valid measure of validity. Nutrients in serum or plasma such as serum vitamin C may only reflect short term intake, and therefore would only be reasonable to validate short-term methods such as food recalls or records. Additionally, if different participants are used in the validation measure, they may no longer be reflective of the test population (Margetts & Nelson, 1997). These methods may also be more time consuming, costly and invasive than other dietary assessment methods and therefore careful consideration must be taken with each nutrient before adopting biomarkers for choice of validation tool.

Table 2.2 Common Validation Instruments in Dietary Assessment adapted from Margetts and Nelson (1997), Cade et al. (2002), and Willett (2012)

Instrument	High expense	Strengths	Limitations
Doubly-labelled water	Y	▪ No error associated with misreporting or memory ▪ No error associated with food composition tables	▪ Too expensive for routine use ▪ Assumptions of model may be inaccurate in obesity or high alcohol consumption ▪ Energy only
Urinary nitrogen only	N	▪ No error associated with misreporting or memory ▪ No error associated with food composition tables	▪ Protein only ▪ Risk of incomplete samples ▪ If PABA used to confirm complete samples, analysis is affected by some products including paracetamol ▪ Results interlinked with body processes including from digestion to excretion, homeostatic mechanisms and some disease states
Weighed/estimated records	N	▪ Errors in test method are often not correlated e.g. memory, open ended format and measurement of portion sizes if weighed	▪ Misreporting ▪ Insufficient number of days recorded are unreflective of usual diet ▪ limitations associated with recording process including altering food habits
Multiple 24-hour recalls	N	▪ Can be used when literacy or cooperation of the participant is limited ▪ Little participant burden ▪ Non-invasive ▪ Less likely to influence the actual diet of participants	▪ Misreporting ▪ Insufficient number of days recorded are unreflective of usual diet ▪ Limitations in accuracy of report from errors in conceptualisation and memory
Biochemical measurements of nutrients in blood or other tissues	Y	▪ No error associated with misreporting or memory ▪ No error associated with food composition tables	▪ Results interlinked with body processes including from digestion to excretion, homeostatic mechanisms and some disease states ▪ Invasive ▪ Error associated with biochemical assay ▪ Nutrient specific

Time frame of Reference

Both test and reference method must assess diet over the same time span including current, usual or past intake (Cade et al., 2002). For example, if the objective is to retrieve information for the individual's *usual* intake of foods or nutrients then the choice of analysis of individual foods or nutrients must reflect the same time frame (Cade et al., 2002; Margetts & Nelson, 1997). FFQ's are typically validated using a reference method for example multiple day 24-hour recalls that reflect usual intake of the same timeframe, typically of one year (Serra-Majem et al., 2009).

Administration Sequence

The test method should ideally be tested prior to the reference method and the reference method should be spaced out enough to limit the test method from influencing the responses of the reference method (Cade et al., 2002; Margetts & Nelson, 1997). As the assessment itself may draw the participant's attention to their own diet, it is important to note that this interval between methods must not be too long to limit a change in seasonal variation impacting on the dietary intake and responses of the reference method (Margetts & Nelson, 1997).

2.7 Statistical Analysis

There is no universal consensus in the literature on a single statistical method to measure validity. More than one method may be used to allow greater credibility of results and robustness of the validation process (Cade et al., 2002; Masson et al., 2003; Serra-Majem et al., 2009). A common set of statistical methods used in FFQ validation studies include: 1. comparing means, medians or differences, 2. correlation analysis, 3. cross-classification analysis, and 4. Bland-Altman Limits of Agreement analysis. A systematic review of FFQ design, validation and use by Cade et al. (2004), found that 83% of studies used correlation coefficients as a comparison method, whilst the kappa statistic and student's *t* test were other common methods used for comparison. Cade et al. (2004) recommended the use of Bland-Altman methods, in conjunction with correlation or regression analysis. Additionally, when absolute intakes are required, comparing group means should be assessed. An 2012 systematic review (Zaki et al., 2012) of 30 nutrition studies showed that 83% (n=25) of studies used Bland-Altman Limits of Agreement, 43% (n=13) of studies used correlation

coefficients, and 13% (n=4) of studies used either coefficient of determination (r^2), comparison of means, or comparisons of slopes or intercepts. The authors highlighted the use of correlation coefficients, coefficient of determination, regression and comparing means as inappropriate, however, all methods, including Bland and Altman have received criticism (Zaki et al., 2012).

Comparing means or medians

Where it is required to assess differences between groups, the means or median between these groups should be examined and can be used to test if these groups are significantly different from one another (Cade et al., 2002; Gibson, 2005). Means should only be used on normally distributed data, while medians should be used for non-normally distributed data. Testing data for normality first will determine the correct test to use. For normally distributed or parametric data, Paired t-tests may be used (Borrud, Pillow, & Newell, 1989; Cade et al., 2002), however, food data are unlikely to be parametric or amenable to log-transformation. In this case the Wilcoxon's signed rank sum test or other non-parametric tests may alternatively be appropriate to compare medians (Cade et al., 2002). Relative validity can be determined using the median as the 50th percentile and other selected percentiles such as the 25th and 75th percentile to test for their comparability (Gibson, 2005; Margetts & Nelson, 1997).

Correlation coefficients

Comparisons between test (FFQ) and reference methods are often assessed by measuring the degree of association between the test and reference method by calculating the correlation coefficients (Bland & Altman, 1986; Cade et al., 2004; Gibson, 2005). The test measure represents a strong relationship with the reference measure if the correlation coefficient (r) is statistically significant (Margetts & Nelson, 1997).

Correlation coefficients are most often calculated using Pearson or Spearman's correlation coefficients. If the data is normally distributed or can be log-transformed to obtain a normal distribution, the Pearson's correlation coefficient can be used. If the data is non-normally distributed the Pearson's correlation may give misleading results and therefore the Spearman's rank correlation coefficient should be used (Masson et al., 2003). However, correlation coefficients should not be used alone as a measure of validity as they do not measure the agreement between two methods but instead only the 'degree to which the other

methods is related' (Cade et al., 2004). In this case, even when the correlation coefficient is high, there may be poor agreement. However, as correlation coefficients give a single measure of association and are the most common statistical procedure applied in studies, they can be used to compare between study findings (Cade et al., 2004; Serra-Majem et al., 2009). All but one study presented in Table 2.3 used correlation coefficients. Pearson or Spearman's correlations for energy ranged from 0.21 for a Samoan population living in NZ (Bell et al., 1999) to 0.61 and 0.65 for German adults from the EPIC-Potsdam study before and after deattenuation, respectively (Kroke et al., 1999). Deattenuation is often used to reduce the between-person variation of correlations. Deattenuation or adjusting correlation coefficients, for instance, adjusting for variables including energy, gender or sex, can often be applied as they may make correlations more reliable by reducing correlated errors between the FFQ and reference tools (Kipnis et al., 2003). This was observed following adjustment for energy and deattenuation in the EPIC-Potsdam study. For example, after deattenuation and energy adjustment protein had a correlation coefficient of 0.84 from a crude unadjusted correlation of 0.51. Improvements were also noted in other studies (Beck et al., 2018; Bell et al., 1999; Hodge, Patterson, Brown, Ireland, & Giles, 2000; Kroke et al., 1999; Steinemann et al., 2017; Verger et al., 2017; Yuan et al., 2017).

Cross-classification

Questionnaires often use ranking to assess the agreement between individual subjects along the distribution of intake (Masson et al., 2003). This method is also known as cross-classification where subjects are divided into categories differentiating between low and high levels of intake such as between thirds (tertiles), fourths (quartiles) or fifths (quintiles). A percentage is calculated for subjects placed into the same category of intake as are those that are placed in the opposite category of intake for each method. Calculating those that are 'correctly classified' in the same category of intake and those that are 'grossly misclassified' into the opposite category, show whether the test measure is categorised the same or differently than the reference method (Cade et al., 2002).

FFQ validation studies use a variation of classifications across studies, including tertiles, quartiles and quintiles as described in Table 2.3. Results may be reported as a percentage of subjects in exact agreement, ± 1 category of agreement, and those grossly misclassified into opposite categories of intake (Cade et al., 2002). Variations between

studies make comparisons difficult. Cohen's weighted kappa statistic is often used alongside cross-classification. This provides a summary measure of agreement of cross-classification and also accounts for one error in cross-classification where those participants whose classification were based on chance are included in the percentage agreement (Cade et al., 2002; Gibson, 2005; Masson et al., 2003).

Bland-Altman

Another method to assess agreement is the Bland-Altman Limits of Agreement (LoA) proposed by Bland and Altman (1999). The Bland-Altman method, unlike the correlation coefficients, makes no assumption whether the test or reference method is superior to the other and relies on the investigator to make this interpretation (Margetts & Nelson, 1997). Bland and Altman argue agreement must be assessed in two ways: how well the measurements agree on average and how well the methods agree for individuals (Bunce, 2009; Margetts & Nelson, 1997). Average agreement is assessed by plotting the mean difference of the test and reference method against the average of the two measures. One method may have a tendency to consistently exceed the other. This bias can be observed in the plot as a deviation from zero (Bland & Altman, 1999; Bunce, 2009).

Second, agreement for individuals can be assessed using the 95% LoA, calculated as two standard deviations of the mean difference. This gives a confidence interval where 95% of variation in the differences should fall if the differences are normally distributed and allows identification of any outlying or extreme values (Bland & Altman, 1999). The 95% LoA illustrates the magnitude of the systematic difference.

Plotting the mean difference and average intake between methods on a scatter plot further enables identification of any discrepancies or variability in the differences of the test and reference methods across the range of intake (Bunce, 2009). This is commonly observed as an increase in variability of the data as the average intake increases (Bland & Altman, 1999), and can be further examined by the use of Spearman's rank correlation coefficient.

Table 2.3 comprises a comparison of FFQ validation studies against various reference methods. The table illustrates the use and results of different statistical methods to assess the agreement of nutrients or food groups between test and reference methodologies.

Table 2.3 Food Frequency Questionnaires Validation Studies Against Various Reference Methods in the Literature

Author and year	Sample population	FFQ description	Reference Method	Outcome	Statistical Methods			Authors Conclusions
					Correlation	Cross-classification	Bland-Altman Analysis	
(Beck et al., 2018)	- New Zealand - Female: 110 - Age: 32.4 ± 7.6	- 220 item - semi-quantitative - Self-administered	4-day WFR	Energy, 25 nutrients	-Pearson's correlation coefficients - Energy: 0.32, - Nutrient range: Lowest 0.11 iron Highest 0.59 SFA; - Energy adjusted range: Lowest 0.23 vitamin D Highest 0.67 magnesium	- Energy: -Same quartile %: 32.7 -Opposite quartile %: 7.3 -Unadjusted nutrients -Same quartile range: Lowest 21.8 phosphorus Highest 41.8 thiamine, -Opposite % range: Lowest 2.7 SFA Highest 10.0 iron; -Energy adjusted range: -Same quartile: Lowest 27.3 folate Highest 50.0 total fat -Opposite quartile: Lowest 0.9 MUFA, magnesium, calcium Highest 10.0 iron.	-As mean intake increased, the difference between the two methods increased. -Bias observed for all nutrients except for cholesterol, vitamins B6, E, folate, phosphorus, iron and zinc.	The FFQ demonstrated reasonable validity for ranking individuals according to nutrient intake
(Bell et al., 1999)	New Zealand Samoan -Female: 31 -Male: 24 -Age: 43 ± 14	- 89 item -Quantitative -Self-administered	7-day WFR	Energy 27 Nutrients	-Spearman's correlation coefficients unadjusted: - Energy 0.21, -Nutrient range: Lowest 0.03 thiamin Highest 0.48 B12; -Energy adjusted range: Lowest -0.12 B6 Highest 0.54 calcium	- Energy: -Same tertile %: 45; -Opposite tertile %: 18; -Nutrients range: Lowest 29 folate and vitamin C Highest 53 sugar -Opposite range (%): Lowest 9 calcium Highest 22 fibre and thiamin	-Most participants fell within ±2SD -Mean differences were large -Limits of agreement were wide	The DR and FFQ did not compare well in a Samoan population living in NZ. The FFQ may have given a better estimate of true EI in this population.

Author and year	Sample population	FFQ description	Reference Method	Outcome	Statistical Methods			Authors Conclusions
					Correlation	Cross-classification	Bland-Altman Analysis	
(Bountziouka et al., 2012)	Greece - Female: 259 - Male: 173 - Age: 46 ± 16*	- 69 item -Semi-quantitative - Self-administered	3-day EFR	Energy 3 Macro-nutrients 12 Food groups	-Kendall's tau-b range food groups: Lowest 0.12 legumes Highest 0.47 stimulants; Energy: 0.17 Nutrient range: Lowest: 0.14 fat Highest: 0.21 CHO	-Energy Same quartile %: 32 Opposite quartile %: 9.6	-Mean differences and LoA acceptable. -As intake increased, FFQ tended to underestimate consumption of dairy products, meat, fish and legumes and overestimate eggs, starchy products, alcohol, and fats and oils. -No outliers except protein	Relative validity for energy and macronutrients and Moderate validity for some food groups including alcohol
(Hodge et al., 2000)	-Australia -Female: 63 -Age: 33.3 ± 9.5*	-74 item -Semi-quantitative -Self-administered	7-dayWFR	Energy and 26 Nutrients	-Pearson's unadjusted Energy: 0.25 -Nutrient range: Lowest 0.14 retinol & vitamin A Highest 0.60 alcohol. Spearman's unadjusted Energy: 0.23 -Nutrient range: Lowest 0.16 sodium Highest 0.58 alcohol -Energy adjusted Lowest 0.22 sodium Highest 0.70 CHO	-Same quintile range (%): -Unadjusted data: Lowest 22.2 sodium Highest 38.1 niacin -Log_e and energy-adjusted: Lowest 20.6 vitamin A Highest 50.8 iron; -Fewer than 10% grossly misclassified in both unadjusted or adjusted data.	-Mean differences at group level varied <10% -LoA large. Log-transformation improved estimates	The ACCVFFQ performs adequately for Ango-Celtic premenopausal women and performs as well as other FFQ's currently in use
(Kroke et al., 1999)	- Germany (EPIC) -Female: 59 -Male: 75 -Age: 56 ± 7.6*	-146 item -Semi-qualitative -Self-administered	-3x 24h diet recall; -24h urinary nitrogen; DLW	Energy, 12 macro-nutrients	-Pearson's correlation coefficients: unadjusted crude -Energy: 0.61; -Nutrient range: Lowest 0.47 PUFA Highest 0.83 alcohol -Deattenuated	-Correctly classified into the same quintile: Energy 32.8; -Nutrient range correctly classified: Lowest 26.1 fibre Highest 49.3 alcohol; -Opposite quintile:	-Considerable mean difference indicating underreporting for all but one participant -Wide LOA for energy from 2000 to -7000kj indicating discrepancies between methods.	The FFQ gave Comparative relative validity for the study population.

Author and year	Sample population	FFQ description	Reference Method	Outcome	Statistical Methods			Authors Conclusions
					Correlation	**Cross-classification**	**Bland-Altman Analysis**	
					Energy: 0.65; Nutrient range: Lowest 0.50 cholesterol Highest 0.88 alcohol -Adjusted for energy Lowest 0.50 fibre Highest 0.81 alcohol -Energy adjusted & deattenuated range Lowest 0.54 fibre Highest 0.86 alcohol.	Energy 0.0 nutrient range; Lowest 0.0 total fat, monosaccharide, disaccharide, polysaccharide and alcohol Highest 3.7 total carbohydrate -Energy adjusted -Correctly classified Lowest 30.6 PUFA Highest 51.5 alcohol; -- Opposite quintile range: Lowest 0.0 fat, SFA, MUFA, alcohol -Highest 3.7 fibre.	-Increase in differences between methods as energy increased	
(Metcalf et al., 1997)	- New Zealand -Female:55 -Male: 121 -Age: 50.0 ± 0.46*	-142-item -Semi-quantitative -Self-administered	3-day EFR	Energy, 10 Nutrients	-Spearman rank correlation coefficients: -Europeans: Energy: 0.41 Lowest 0.41 fat Highest 0.81 alcohol; -Polynesians: Energy: 0.44 Lowest 0.36 fibre Highest 0.56 alcohol	Not measured	Not measured	The validity between the FFQ and 3DR was good for most nutrients however, there was some overestimation in some nutrients for each ethnic group

Author and year	Sample population	FFQ description	Reference Method	Outcome	Statistical Methods			Authors Conclusions
					Correlation	Cross-classification	Bland-Altman Analysis	
(Sharpe, Page, Gamble & Sharpe., 1993)	-New Zealand -Female: 52 -Male: 50 -Age: 25-75 years	75 items -Semi-qualitative -Self-administered	7-day WFR	Energy and 31 nutrients	-Spearman's correlation coefficients: Energy: 0.70 -Nutrients: Lowest 0.21 vitamin A Highest 0.71 alcohol	Same quintile range: Lowest: 30% sodium Highest: 75% caffeine Opposite quintile: Lowest: 0% energy, sugar, fibre, fat, SFA, PUFA MUFA, caffeine, sodium, calcium, phosphorus, vitamin E, thiamine, riboflavin and folate Highest: 10% protein and potassium	Not assessed	Good agreement of energy and a wide range of nutrients. Suitable for use in cardiovascular risk assessment in New Zealand population.
(Steinemann et al., 2017)	Switzerland -Female: 34 -Male: 22 -Age: 40.0 ± 18.6*	127-item -Semi-qualitative -Self-administered	4-day WFR	Energy, 4 Macro-nutrients & 25 Food groups	-Spearman's correlation: Energy: 0.32 -Unadjusted macronutrient range: Lowest 0.24 CHO Highest 0.46 protein -Energy adjusted: Energy: 0.36 -Macronutrient range: Lowest 0.27 CHO Highest 0.55 protein Food groups Adjusted: Lowest 0.09 soup Highest 0.92 alcohol.	Not measured	-Mean differences for showed both over- and under-estimation by the FFQ for both nutrients and food groups. -Tendency for larger differences between FFQ and WFR with increasing energy intake	Moderate relative validity for protein and some food and beverages including alcoholic beverages.
(Tueni, Mounayar, &	Lebanon -Female: 286 -Male: 280	-56 traditional	7-day Weekly diet recall	11 Food Groups, Energy &	-Spearman's correlation -Food groups:	Food groups: -Same third (%):	Not calculated	In the Mediterranean regions, an FFQ

Author and year	Sample population	FFQ description	Reference Method	Outcome	Statistical Methods			Authors Conclusions
					Correlation	Cross-classification	Bland-Altman Analysis	
Birlouez-Aragon, 2018)	-Age: 40.57 ± 15.45*	mixed dishes -Semi-qualitative -Interview-administered		20 Nutrients	Lowest men 0.22 vegetables with meat; Women 0.30 fish Highest men 0.95 cereals, pastries and dairy products; women 0.86 dairy products -Energy: men 0.78; women 0.69 -Nutrients: Lowest men 0.66 retinol; women 0.58 PUFA Highest men 0.87 folates; women 0.69 fat, folate, potassium	Lowest Men 39.3 vegetables with meat; women 39.5 total vegetables Highest men 91.8 fish; women 79.0 dairy products -Misclassified (%) Lowest men 0.0 cereals and pastries; women 2.4 dairy products Highest: mean 14.6 vegetables with meat; Women 22.7 fish -Nutrients: -Same tertile Lowest men 59.3 PUFA and retinol; women 55.2 MUFA Highest men 75.4 cholesterol; women 61.9 vitamin E		for traditional food with a photogenic atlas has an acceptable level of validity as a tool for dietary assessment and may be useful to rank individuals according to their usual consumption of nutrients and traditional foods
(Verger et al., 2017)	-France -Female: 172 -Male: 152 -Age: 53.5 ± 8.4*	-159 items - Semi-qualitative -Self-administered	-3x 24h diet Recall	Energy, 28 Nutrients & 22 Food groups	-Pearson's correlation coefficients: Energy: 0.276; -Unadjusted nutrients: Lowest 0.119 vitamin A Highest 0.640 alcohol -Energy adjusted nutrient range: Lowest 0.212 vitamin A Highest 0.823 fibre -Food groups range: Lowest 0.155 eggs and egg dishes	Energy -Same tertile %: 41.4 Misclassified 13.6%. -Correctly classified (%) -Tertiles -Nutrient range: Lowest 38% cholesterol Highest 50.9% niacin Mean 44.4%; -Opposite tertile range: Lowest 7.7% fibre Highest 21.3% PUFA Mean 12.9%	-General overestimation of nutrient intake by the FFQ compared to the DR -Spearman rank correlation coefficients of mean intakes and difference between intake range: Lowest -0.361 vitamin D Highest 0.391 vitamin C -Food groups range: Lowest -0.53 fats	The FFQ had an acceptable level of validity although low to moderate validity for some nutrients and food groups

Author and year	Sample population	FFQ description	Reference Method	Outcome	Statistical Methods			Authors Conclusions
					Correlation	Cross-classification	Bland-Altman Analysis	
					Highest 0.650 alcoholic beverages.		Highest 0.457 milk. -Potential proportional bias for sugars, vitamin A, C, D and potassium; fish and fish products, milk, fats, spreads, soft drinks and fruit juices, and fruits.	
(Wong, Parnell, Black, & Skidmore, 2012)	-New Zealand adolescents -Female: 25 -Male: 16 -Age: 15.1 ± 0.9*	72 items -Non-quantitative -Self-administered	4-day EFR	34 Food groups	-Spearman's correlation range: Lowest 0.04 convenience foods Highest 0.70 standard milk	-Same tertile: Lowest 27% leafy green vegetables and potatoes; Highest 78% meat alternatives; Opposite third: Lowest: 2% standard milk Highest: 29% convenience foods	Not measured	The FFQ showed reasonable validity in most food groups to rank food intakes
(Xinying, Noakes, & Keogh, 2004)	-Australia -Female: 65 -Male: 53 -Age: 58 ± 9*	74 items - Semi-quantitative -Self-administered	7-day WFR	Energy & 10 Nutrients	-Pearson's correlation Energy: 0.39 Lowest 0.22 cholesterol Highest 0.78 alcohol	-Same quintile Lowest 21% PUFA Highest 37% energy from SFA	-Mean nutrient intakes varied by <20% -95% LoA wide. Energy LoA range from -4.9 to 5.5 MJ suggesting the FFQ inappropriate for use for individual dietary assessment	The FFQ is an appropriate tool to use to estimate group intake in clinical trial populations
(Yuan et al., 2017)	-U.S.A -Female: 632 -Age: 61 ± 10*	152 items -Semi-quantitative FFQ's -Self-administered	7-day WFR & 4x 24-h diet recall	Energy & 44 Nutrients	-Spearman correlation: WFR Energy: 0.28 -Unadjusted nutrient range: Lowest 0.28 sodium and polyunsaturated fat Highest 0.86 alcohol. -24H-FRs Energy 0.30	Not measured	-No obvious systemic bias detected for some nutrients	The SFFQ is a reasonably valid tool for measuring nutrient intakes when compared to reference methods

Author and year	Sample population	FFQ description	Reference Method	Outcome	Statistical Methods			Authors Conclusions
					Correlation	Cross-classification	Bland-Altman Analysis	
					Unadjusted nutrient range: Lowest 0.23 lycopene Highest 0.54 total sugar -Adjustment for energy using energy density and residual method and deattenuation improved correlations between FFQ in both & WFR and 24-hour recall methods			

FFQ, Food Frequency Questionnaire, WFR, Weighed Food Record, EFR, Estimated Food Record, DLW, Doubly labelled water F, females, M, males, admin-, administration, PUFA Polyunsaturated fatty acid, SFA, Saturated fatty acid, CHO carbohydrate, EI, energy intake, eq, equivalents
*Age ± standard deviation

2.8 Food frequency questionnaire validation studies in New Zealand

In New Zealand there are few current and valid FFQ's to measure diet in adults. One recent FFQ has been validated to assess dietary patterns in the New Zealand population for young adult Māori, Pacific and New Zealand women (Beck et al., 2018) and another FFQ has been validated for nutrient intakes of New Zealand adults (Sam et al., 2012). However, in these studies, the Māori and Pacific ethnic groups are often under-represented with only 5% of study participants representing Māori and Pacific Island ethnicity in Sam et al. (2012), and 21% in Beck et al. (2018). 8% of which were Pacific women, compared to 81% from NZ European decent. The FFQ study population should reflect the target population, as the way the population groups may respond to the questionnaire may differ (Cade et al., 2002).

One New Zealand validation study between European, Māori and Pacific Island men and women published in 1997, used a 142-item FFQ against a 3-day diet record reference method (Metcalf et al., 1997). The FFQ was validated separately between populations and found correlation coefficients between the FFQ were better correlated with the diet record in the Māori and Pacific island population than the European population for energy and nutrients. Energy intake also differed between groups with total energy intake 5% lower in the European group on the FFQ than the food record, compared to a higher energy intake of 8% and 22% in the Māori and Pacific population respectively when the ratio of energy intake to resting metabolic rate was calculated. The authors concluded the Māori and Pacific population was more likely to under-report their dietary intake on the 3-day food diary while Europeans were more likely to under-report total energy intake on the FFQ. Pacific Islanders were also more likely to over-report energy intake on the FFQ.

Similar findings were reported in 1999 by Bell et al. (1999) when validation of energy and nutrient intakes in a Samoan population found poor agreement between a food frequency questionnaire when validated against a 7-day food record. Although the food record is often reported as the gold standard method of measurement, the error associated with this reference method may have not been suitable for use in this population as poorer measures of validation may have reflected misreporting by the reference method. The authors noted many of the participants had not used the scales and measuring equipment supplied and may have underreported some foods such as snacks. Furthermore, the number of days of recording and

administration of diet record may have reduced the validity of the measurement due to alteration of dietary habits from boredom and accuracy of recording. When further analyzed, for just two days of dietary recording, or after removing outliers, accuracy did not significantly improve (Bell et al., 1999). Bell et al. (1999) suggested other methods of collecting dietary data may be more useful in this population such as collecting supermarket dockets or applying external markers of validation such as biological markers to evaluate dietary intake.

Overall, FFQ's must be culturally appropriate to be relevant for use in the intended population. New Zealand validation studies have predominantly reflected the NZ European population (Beck et al., 2018; Sam et al., 2012) while few have validated FFQ's separately between ethnicity group, and those that have, are no longer current (Bell et al., 1999; Metcalf et al., 1997). This highlights the need for a validated FFQ to be culturally appropriate to separately assess the nutrient intake of both NZ European and Pacific populations living in New Zealand.

2.9 Summary

In this literature review, I have discussed various dietary assessment methods including 24-hour recalls, food records, diet histories, and food frequency questionnaires (FFQ). The review discusses the strengths and limitations of each method and the importance of the validation of dietary assessment methods. Furthermore, the review describes the criteria for an appropriate validation reference tool and discusses each method. Previous validation studies using FFQ's in the literature are described with details of the statistical methods most commonly used to assess agreement. Finally, the review highlights the need for a validated FFQ in New Zealand women that is culturally specific to both NZ European and Pacific populations.

Chapter 3: Research Manuscript: Validation of a food frequency questionnaire to assess nutrient intakes in women participating in the PRedictors linking Obesity and gut MIcrobiomE (PROMIsE) Study

3.1 Abstract

Aim To validate a semi-quantitative food frequency questionnaire in 18-45-year-old pre-menopausal adult NZ European and Pacific women participating in the PROMIsE study, living in the greater Auckland.

Methods Participants included 287 premenopausal women living in New Zealand of NZ European (n=161) and Pacific (n=126) ethnicity. Women completed an FFQ (NZWFFQ) designed to assess the dietary intake of 31 nutrients over the previous month and a five-day estimated food record (5d-FR). Relative validity was assessed by comparing the nutrient intakes of the NZWFFQ and 5d-FR using Wilcoxon signed rank test, Spearman's correlation coefficients, cross-classification, weighted kappa statistic and Bland-Altman analysis. Validity was evaluated for crude and energy adjusted data for the total group and separately for NZ European and Pacific ethnicity.

Results The nutrient intake of the NZWFFQ was higher than the 5d-FR overall for all nutrients (range: 6%-113% difference) except iodine (-16%). Correlation coefficients ranged from 0.07 for iodine in the unadjusted total group to 0.63 for alcohol. The highest energy correlation coefficients were for energy adjusted NZ European data (0.17-0.73) and were lowest for the unadjusted Pacific data (-0.02-0.47). Classification into same and adjacent quartiles of intake, and gross misclassification into opposite quartiles, were respectively 77.5% and 5.41% for the total group, 81% and 3.6% for the NZ European group, and 71.2% and 7.6% for the Pacific group for energy adjusted data. The weighted kappa showed slight to moderate agreement for the total group (0.12-0.47), slight to moderate agreement (0.16-0.54) for NZ European, and slight to fair agreement (-0.10-0.28) for the Pacific group. Bland-Altman analysis showed wide limits of agreement for nutrients in each group, with wider limits of agreement and larger mean differences for the Pacific group.

Conclusion: The NZWFFQ gives good validity for ranking NZ European women by nutrient intake and slight to fair validity for ranking Pacific women by nutrient intake. As most nutrients were overestimated by the NZWFFQ it is not a suitable tool to use for estimating absolute nutrient intake.

3.2 Introduction

Non-communicable diseases (NCDs) are a major concern in New Zealand and account for 89% of all deaths in New Zealand (WHO, 2003). NCDs including cardiovascular diseases, diabetes, and some cancers contribute to the long-term conditions that are the most significant cause of, disability and death in New Zealand (MOH, 2017a). Obesity rates have also increased, with a 6% rise in obesity over the last decade (MOH, 2018). This is particularly prevalent in the Pacific population where 91% of Pacific women are overweight or obese compared to 64% of European women.

Diet is a major modifiable risk factor for many of these NCDs (WHO, 2003; Willett, 2012; Willett et al., 2006). Changes in dietary and lifestyle patterns towards poor diet, such as an increased intake of energy-dense micronutrient poor foods contribute towards the increased risk of these diseases (WHO, 2003). In order to make further diet-disease associations, diet must be investigated. The use of dietary assessment tools are often used for this purpose in epidemiological studies by using Food Frequency questionnaires (FFQ) due to their low cost and ease of administration (Cade et al., 2004; FAO, 2018; Lee & Nieman, 2007). FFQ's however, are not free of error, and therefore the validation of FFQ's are essential when evaluating diet as a risk factor for chronic disease (Margetts & Nelson, 1997; Molag et al., 2007).

FFQ's must be validated and up-to date for use in each population group being assessed (Cade et al., 2002). Current and valid FFQ's for use in the New Zealand population are lacking. Only two studies (Beck et al., 2018; Sam et al., 2012) have validated FFQ's for use in the last decade and only one has be validated for women (Beck et al., 2018). Furthermore, there has been no recent FFQ validated separately between ethnicity groups, and sample sizes of some population groups such as Māori and Pacific have not been large enough to do so (Beck et al., 2018; Sam et al., 2012).

The current study seeks to assess the relative validity of a previously validated FFQ in a new population of premenopausal NZ European and Pacific women living in NZ participating in the PROMIsE study.

3.3 Materials and Methods

Study population and design

The participants in this sub-study were recruited as part of the PROMIsE ("Predictors linking Obesity and gut MIcrobiomE") study (n=324). The PROMIsE study is a cross-sectional study targeting New Zealand European and Pacific women with the aim to examine the relationship between the gut microbiome and predictors of obesity. Participants were recruited from the Auckland population in New Zealand between July 2016 and September 2017. The study took place at the Human Nutrition Research Centre at Massey University (MU) in Auckland. Inclusion in the study required subjects to be female, between 18 and 45 years of age, a BMI of either 18.5-24.9kg/m^2 and ≥30kg/m^2, be of New Zealand European or Pacific ethnicity, be generally healthy without any chronic illnesses or health conditions, not to have had bariatric surgery, be taking any medications affecting the immune system or for any chronic disease, be pregnant or breastfeeding, or following a severely restrictive diet, not be allergic to milk or unable to comply with study protocol requirements. Ethical approval for the PROMIsE study was obtained from the Health and Disability Ethics Committee, Southern Region, Ethics Reference 16/STH/32. Written informed consent was obtained from all participants. For inclusion in this sub-study, participants completed an electronic New Zealand women's food frequency questionnaire (NZWFFQ) and a 5-day estimated food record (5d-FR) as the reference method. The NZWFFQ was completed within a period of 2 weeks following the 5d-FR. Both methods are described below.

Participants were excluded from the analysis if they had incomplete or missing dietary data, or if they under- or over-reported their energy intake based on Goldberg cut-offs. These cut-offs were however were extended for over reporters to a reported daily energy intake of >25,000 kJ, or <2100KJ for under-reporters, as have previously been used for ethnic minority populations (George, Milani, Hanss-Nuss, Kim, & Freeland-Graves, 2004; Lawn, 2017). Additionally, data was checked for plausibility, where those who had an unrealistic high or low energy intake, or an unrealistic dietary pattern were asked to clarify their intake (Ministry of Health, 2011). For example, a participant would be excluded they consistently selected 4+ times per day for a number of foods within and across food groups. A total of 20 participants were excluded due to over-reporting of energy intake on the NZWFFQ (>27,000kJ) and

unrealistic patterns of servings reported. Seventeen participants were excluded from the study due to underreporting on the 5d-FR. A total of 287 participants were included in the analysis.

Reference method – 5-day estimated food record

Participants were allocated five non-consecutive days in which to complete an estimated food record at home between two data collection days. Days were allocated to ensure that all the days of the week were equally represented in the final sample. They were given detailed instructions on how to record their dietary intake on their first visit to the Nutrition Laboratory, MU. These included watching an explanatory video, followed by detailed verbal and written instructions on completion techniques. A pictorial guide was given as a supplementary booklet, with codes to assist them in correctly identifying portions consumed. Participants were also encouraged to collect and bring in any food packaging to their second appointment. Participants were then required to complete a 5-day estimated food record on their allocated days over a period of 10 days. A trained dietitian reviewed the completed 5d-FR with each participant on their second visit to the Nutrition Laboratory, 11 to 14 days following the first visit, to cross-check the 5d-FR and clarify any further information.

The NZ Women's Food Frequency Questionnaire

The validated New Zealand Women's Food Frequency Questionnaire (NZFFQ) (Beck et al., 2018) was developed from the food list from the 1997/1998 New Zealand Adult Nutrition Survey and included additions from the 2008/2009 New Zealand Adult Nutrition Survey results. The inclusion of culturally appropriate foods in the NZWFFQ were reviewed by one Pacific and one Maori cultural advisor. The final NZWFFQ is a 220-item semi-qualitative Food Frequency Questionnaire designed to assess usual food intake in New Zealand women over the previous month.

Nutrients of interest for analysis included: energy, macronutrient (protein, fat: total, saturated, polyunsaturated, and monounsaturated fat; carbohydrate: total, sugar, fibre) and micronutrient (vitamins: A, C, D, E, B1, B2, B3, B6, B12, folate; minerals: zinc, calcium, iron, phosphorus, magnesium) and alcohol intake. The final FFQ comprised of 220 food items under 16 food categories: milk and milk products, bread, breakfast cereals and porridge, starchy foods, meat, poultry, fish and seafood, fats and oils, eggs, legumes, vegetables, fruits, drinks, dressings and sauces, miscellaneous, and other, allowing inclusion

of any foods not included in the NZWFFQ. Supplementary questions in food categories were added to capture any usual additions to food e.g. during cooking, and quantity descriptions were used to enhance familiarity to portion sizes for food items e.g. palm sizes. Frequency of intake was assessed using nine categories ranging from 'never' to 'four plus times per day' as previously described in Beck et al. (2018). Participants completed the NZWFFQ in an online format with supervision from trained research staff during their second visit to the Nutrition Laboratory and took 25 minutes to complete.

Nutrient analysis

For nutrient analysis, data from both the NZFFQ and 5d-FR were entered into Foodworks version 8 (Xyris Software, 2013, Queensland, Australia) by trained nutritionists and dietitians. Foodworks uses the New Zealand Food Composition Database FOODfiles, 2014 (Plant & Food Research & MOH, 2014) to determine nutrient intakes. AusFoods 2015, developed by Xyris software or AusNut 2013 were used where foods were not present on the Foodworks database. Each food item on the NZWFFQ was matched to a food item in Foodworks, recipes and home cooked meals were added and a 'new food' were added into Foodworks when no suitable food was present in the databases. Participants were contacted via email to clarify any further questions. Supplement intake data was not used in the analysis.

The NZWFFQ was exported onto an excel spreadsheet and was checked for missing data by trained nutritionists and dietitians before being added into the Foodworks database (version 8). Some nutritional information panels (NIP) from food packaging were provided by participants of foods consumed during the completion of the 5d-FR. When no suitable food items were present on the database a new recipe was added from the NZ Edmonds cookbook or a composite item was selected. Supplementary questions on preparation and cooking methods were used to guide decisions on foods that required substitution. In some cases, one food item in the NZWFFQ covered multiple related foods (e.g. onions, leeks, celery) and one food item was used to represent the nutrient content of these food items (e.g. onions).

Statistical analysis

All statistical analysis was undertaken using IBM SPSS version 23 software for Windows (IBM Corp, 2016). Data was only analysed for women who had completed both the NZWFFQ and 5d-FR.

The normality of distribution for energy and nutrient intake obtained from the NZWFFQ and the 5d-FR was checked by Kolmogorov-Smirnov and Shapiro-Wilk tests and histograms. A *P*-value <0.05 was considered statistically significant (Field, 2013). Most nutrients were not normally distributed and were logarithmically transformed to achieve normal distribution. As most nutrients were still not normally distributed, all results were presented as medians with their corresponding 25th and 75th percentiles. Categorical data was reported as numbers and percentages.

Relative validity of the NZWFFQ was assessed for energy and each nutrient of interest by comparing with the 5d-FR. Data for both methods were adjusted for energy intake using the residual method (Willett & Stampfer, 1986).

Comparison between median of each method to assess the agreement at group level was evaluated through Wilcoxon-signed rank test due to the non-normal distribution of the data. P-values were significantly different at equal to or less than 0.05 (Lombard, 2015).

Spearman's correlations were used to assess the strength and direction of the association of the NZWFFQ and 5d-FR to assess agreement at an individual level. Correlation coefficients were described according to Cohen (1988) and Hopkins, Marshall, Batterham, and Hanin (2009) 0.1 very small, 0.1-0.3 low, 0.30 - 0.49 moderate, 0.50 – 0.69 large, 0.70-0.89 very large, ≥0.9 extremely large significance level was set at a p-value of 0.05 (Field, 2013).

Cross-classification were used to assess agreement by ranking individuals into quartiles of intake. Participants classified correctly by both methods into the same and adjacent quartile, and those misclassified into the opposite quartile of intake were calculated as a percentage of intake. Good agreement was defined as having equal to or more than 50% participants classified into the same or adjacent quartile and equal to or less than 10%

participants in the opposite quartile (Lombard, Steyn, Charlton, & Senekal, 2015; Masson et al., 2003).

Cross-classification was further tested using Cohen's Weighed Kappa Statistic (κ) to correct for those included in the correct classification due to chance agreement using the formula $\kappa = Pr(a) – Pr(e) / 1 - Pr(e)$. Pr(a) is the relative agreement between NZWFFQ and 5d-FR and Pr(e) is the likelihood that agreement is attributable to chance. If $\kappa = 1$ methods completely agreed, where if $\kappa = 0$ there is only agreement expected by chance. Kappa statistic was defined as >0.80 very good agreement, 0.61 to 0.80 good agreement, 0.41 to 0.60 moderate agreement, 0.21 to 0.40 fair agreement, <0.20 slight agreement (Lombard et al, 2015).

The Bland-Altman analysis was the fourth method used to assess agreement. Scatterplots were constructed as according to Bland and Altman (1986) to determine the strength of agreement between methods at an individual and group level (Bunce, 2009). Mean differences between methods for each nutrient were computed as described below (Formula 1) and plotted on the Y axis. Average intakes of each nutrient were then calculated between methods and plotted on the X axis (formula 2). Limits of agreement (LoA) were plotted to examine the variability of the differences for individuals. LoA were computed as +2 and -2 Standard deviations of the differences listed as calculated below (formula 3). Spearman's correlation coefficients were then calculated to determine the strength and direction of bias.

$$AD + X_{FFQ}\text{-}X_{FR} \quad (1)$$

$$X = (x_{FFQ} + X_{FR})/2 \quad (2)$$

$$LOA = AD_{mean} \pm 1.96 \times SD_{difference} \quad (3)$$

3.4 Results

Two-hundred and eighty-seven participants, of which 126 (43.9%) Pacific and 161 (56.1%) New Zealand European women completed both the NZWFFQ and the 5-day Estimated Food Diary (see Table 3.1**)**. Their mean age was 29 ± 7 years. Pacific women were significantly younger, with a higher BMI and were more overweight and obese than NZ European women. Overall, the women in this study had a mean ± SD BMI of 28.9 ± 6.8, and 60% of this cohort of women were either overweight or obese and only 40% had a normal weight BMI.

Table 3.1 Socio-demographic characteristics and anthropometric measurements of study participants by ethnic group (n=287)

Characteristics		NZ European (n=161)	Pacific (n=126)	P-value‡	Total (n=287)
Age (years)		31.4 ± 6.95	25.21 ± 6.46	<0.001	29.0 ± 7.0
Body mass index (kg/m^2)		27.63 ± 6.30	30.52 ± 7.04	<0.001	28.9 ± 6.8
BMI category					
Underweight† and normal weight <25	n (%)	79 (49)	34 (27)	<0.001	113 (39.4)
	Mean ± SD	22.03 ± 1.46	22.9 ± 1.64		22.3 ± 1.56
Overweight: 25 - <30	n (%)	12 (7.5)	30 (23.8)	<0.001	42.0 (14.6)
	Mean ± SD	26.1 ± 1.43	27.2 ± 1.40		26.8 ± 1.48
Obese: ≥30	n (%)	70 (43.5)	62 (49.2)	<0.001	132 (46)
	Mean ± SD	34.21 ± 3.00	36.3 ± 5.26		35.2 ± 4.33

Values expressed as Mean ± Standard Deviation or n (%)
†1 participant classified as underweight
‡p<0.05 considered significant

The daily median energy and nutrient intakes, percentage difference in intake, and corresponding unadjusted and energy-adjusted correlation coefficients from the 5d-FR and NZWFFQ were explored firstly for the total group of women **(**Table 3.2**)** and then independently for each ethnicity **(**Tables 3.3 and 3.4**).** Comparing the results from these two dietary intake assessment methods, shows that the NZWFFQ presented statistically higher estimates of intake than the 5-d FR for median energy and all nutrients except for iodine and sodium that was not statistically significant. Spearman's correlation coefficients for unadjusted data ranged from 0.07 (iodine) to 0.63 (alcohol) for the total group of women with an overall average correlation coefficient of 0.27. Adjusting for energy intake improved the correlations between methods ranging from 0.17 (iodine) to 0.66 (magnesium) with an overall average correlation coefficient of 0.41.

Table 3.2 Median nutrient intakes from the NZWFFQ and 5d-FR, and correlation coefficients (n=287) among all NZ European and Pacific women

Nutrients	5d-FR median (25^{th}, 75^{th} percentile)	NZWFFQ median (25^{th}, 75^{th} percentile)	P-value	% difference	Correlation coefficients†			
					Unadjusted r‡	p-value	Adjusted r§	p-value
Total energy (kJ)	8451 (6982, 9633)	9263 (7534, 11987)	<0.001	9.61	0.22**	<0.001	-	-
Protein (g)	82.0 (69.1, 95.9)	96.5 (76.3, 129)	<0.001	17.7	0.26**	<0.001	0.32**	<0.001
Total fat (g)	87.7 (70.3, 108)	97.2 (72.7, 126)	<0.001	10.8	0.30**	<0.001	0.44**	<0.001
SFA (g)	33.3 (26.1, 42.8)	37.1 (26.9, 48.8)	<0.001	11.4	0.37**	<0.001	0.41**	<0.001
PUFA (g)	12.0 (8.93, 14.8)	14.3 (10.2, 18.7)	<0.001	19.2	0.24**	<0.001	0.47**	<0.001
MUFA (g)	33.4 (25.3, 41.1)	35.5 (26.2, 46.7)	0.001	6.29	0.30**	<0.001	0.40**	<0.001
Cholesterol (mg)	286 (199, 399)	307 (214, 455)	0.003	7.34	0.36**	<0.001	0.47**	<0.001
Carbohydrates (g)	192 (152, 235)	220 (164, 283)	<0.001	14.6	0.34**	<0.001	0.55**	<0.001
Sugars (g)	79.2 (60.8, 98.3)	105 (79.0, 135)	<0.001	32.6	0.31**	<0.001	0.44**	<0.001
Dietary fibre (g)	20.3 (16.8, 25.6)	26.5 (20.1, 36.0)	<0.001	30.5	0.23**	<0.001	0.55**	<0.001
Alcohol (g)	0.07 (0.00, 6.39) 5.70 ± 11.8[d]	1.74 (0.11, 6.04) 4.88 ± 7.88[d]	<0.001	2385 -14.4[d]	0.63**	<0.001	0.61**	<0.001
Thiamin (mg)	1.19 (0.93, 1.56)	1.35 (0.94, 1.94)	<0.001	13.4	0.28**	<0.001	0.33**	<0.001
Riboflavin (mg)	1.75 (1.37, 2.12)	2.41 (1.87, 3.50)	<0.001	37.7	0.23**	<0.001	0.26**	<0.001
Niacin (mg)	18.1 (15.0, 23.2)	24.2 (18.6, 33.6)	<0.001	33.7	0.33**	<0.001	0.37**	<0.001
Niacin equivalents (mg)	34.6 (28.6, 40.6)	42.7 (34.1, 57.2)	<0.001	23.4	0.30**	<0.001	0.35**	<0.001
Vitamin C (mg)	61.5 (39.3, 98.7)	131 (84.9, 181)	<0.001	113	0.23**	<0.001	0.40**	<0.001
Vitamin E (mg)	9.03 (7.01, 11.36)	13.0 (9.72, 17.1)	<0.001	44.0	0.18**	0.002	0.46**	<0.001
Vitamin B6 (mg)	2.15 (1.63, 2.70)	3.57 (2.64, 5.04)	<0.001	66.0	0.25**	<0.001	0.22**	<0.001
Vitamin B12 (µg)	3.49 (2.66, 4.48)	4.48 (3.19, 6.82)	<0.001	28.4	0.33**	<0.001	0.33**	<0.001
Folate (µg)	295 (222, 398)	335 (241, 431)	0.001	13.6	0.20**	0.001	0.45**	<0.001
Retinol (µg)	303 (198, 400)	376 (272, 515)	<0.001	24.1	0.23**	<0.001	0.31**	<0.001
Beta carotene equivalents (µg)	2169 (1300, 3389)	4186 (2784, 6015)	<0.001	93.0	0.31**	<0.001	0.40**	<0.001
Sodium (mg)	2595 (2091, 3260)	2566 (1801, 3420)	0.915	-1.12	0.30**	<0.001	0.46**	<0.001
Potassium (mg)	2826 (2349, 3302)	3700 (2802, 4664)	<0.001	30.9	0.12*	0.043	0.45**	<0.001
Magnesium (mg)	292 (246, 366)	372 (290, 476)	<0.001	27.4	0.23**	<0.001	0.66**	<0.001
Calcium (mg)	763 (547, 945)	1002 (721, 1296)	<0.001	31.3	0.24**	<0.001	0.43**	<0.001
Phosphorus (mg)	1344 (1108, 1552)	1577 (1237, 2048)	<0.001	17.3	0.12*	0.038	0.39**	<0.001
Iron (mg)	11.3 (9.11, 13.6)	12.1 (9.25, 16.0)	<0.001	7.08	0.20**	0.001	0.35**	<0.001
Zinc (mg)	9.88 (8.40, 11.6)	11.8 (8.93, 15.3)	<0.001	19.4	0.23**	<0.001	0.29**	<0.001
Selenium (µg)	58.4 (45.5, 77.3)	81.9 (59.3, 122)	<0.001	40.2	0.33**	<0.001	0.44**	<0.001
Iodine (µg)	88.3 (65.9, 116)	74.3 (55.7, 109)	<0.002	-15.9	0.07	0.219	0.17**	0.003

NZWFFQ, New Zealand Women's Food Frequency Questionnaire, 5d-FR, five-day estimated food record, SFA, saturated fat, PUFA, polyunsaturated fat, MUFA, monounsaturated fat
† Spearman's correlation coefficients *(r)*
‡Unadjusted raw dietary data
§ Adjusted for energy intake
¶ Mean and standard deviation
* p <0.05, two tailed test ** p <0.01, two-tailed test

Table 3.3 shows the daily median energy and nutrient intakes, percentage difference in intake, and corresponding unadjusted and energy-adjusted correlation coefficients from the 5d-FR and NZWFFQ when the data were analysed independently for the New Zealand European women. The results from the comparison between methods improved somewhat. The NZWFFQ results were again higher compared to 5d-FR in median energy and all

nutrients except for sodium and iodine with iron non-significantly lower than the 5d-FR **(**Table 3.3**)**. Correlation coefficients ranged from 0.25 (phosphorus) to 0.71 (alcohol) for unadjusted data with an overall mean correlation of 0.37. Following energy adjustment, the results improved further, with correlation coefficients ranged from 0.27 (vitamin B6) to 0.73 (carbohydrates), and an overall mean correlation of 0.50

Finally, Table 3.4 shows the daily median energy and nutrient intakes, percentage difference in intake, and corresponding unadjusted and energy-adjusted correlation coefficients from the 5-d FR and NZWFFQ analysed independently for the Pacific women. This revealed much lower correlations than that for the total group or the New Zealand European women. Pacific women's median energy and all nutrient intakes were much higher from the NZWFFQ than the 5d-FR, showing greater percentage differences for most nutrients**.** Correlation coefficients ranged from -0.02 (iodine) to 0.47 (alcohol) for unadjusted data with an overall mean correlation coefficient of 0.18. Following adjustment for energy, correlation coefficients improved, ranging from 0.05 (iodine) to 0.42 (cholesterol) with an overall mean correlation coefficient of 0.26.

Table 3.3 Median nutrient intakes from the NZWFFQ and 5d-FR, and correlation coefficients (n=161) among NZ European women

Nutrients	5d-FR median (25th, 75th percentile)	NZWFFQ median (25th, 75th percentile)	p-value	% difference	Correlation coefficients† Unadjusted r‡	p-value	Adjusted r§	p-value
Total energy (kJ)	8162 (6985, 9380)	8373 (6757, 10697)	0.012	2.59	0.29**	<0.001		
Protein (g)	84.4 (73.1, 95.0)	86.5 (71.4, 108)	0.014	2.49	0.39**	<0.001	0.41**	<0.001
Total fat (g)	87.3 (71.2, 108)	89.8 (69.3, 116)	0.256	2.86	0.40**	<0.001	0.63**	<0.001
SFA (g)	32.2 (25.5, 42.8)	32.7 (25.3, 44.4)	0.254	1.55	0.43**	<0.001	0.58**	<0.001
PUFA (g)	12.3 (9.39, 14.8)	13.9 (9.79, 18.3)	0.005	13.0	0.42**	<0.001	0.55**	<0.001
MUFA (g)	33.4 (25.1, 41.9)	32.0 (24.1, 42.4)	0.498	4.19	0.45**	<0.001	0.60**	<0.001
Cholesterol (mg)	294 (203, 406)	259 (184, 345)	0.14	11.9	0.48**	<0.001	0.57**	<0.001
Carbohydrates (g)	180 (147, 213)	193 (147, 247)	<0.001	7.22	0.41**	<0.001	0.73**	<0.001
Sugars (g)	77.4 (59.2, 94.8)	98.9 (74.1, 122)	<0.001	27.8	0.44**	<0.001	0.62**	<0.001
Dietary fibre (g)	22.4 (18.9, 28.6)	27.6 (20.3, 34.5)	<0.001	23.2	0.40**	<0.001	0.58**	<0.001
Alcohol (g)	1.71 (0.01, 11.0) 7.59 ±12.1)[d]	3.25 (0.67, 8.05) 6.41 ± 8.96)[d]	0.125	90.1 -15.5[d]	0.71**	<0.001	0.69**	<0.001
Thiamin (mg)	1.17 (0.94, 1.50)	1.17 (0.87, 1.61)	0.612	0.00	0.31**	<0.001	0.45**	<0.001
Riboflavin (mg)	1.78 (1.50, 2.16)	2.20 (1.73, 2.83)	<0.001	23.6	0.41**	<0.001	0.46**	<0.001
Niacin (mg)	17.9 (15.1, 21.2)	21.1 (16.6, 27.6)	<0.001	17.9	0.39**	<0.001	0.44**	<0.001
Niacin equivalents (mg)	34.1 (29.4, 38.8)	38.5 (30.6, 48.2)	<0.001	12.9	0.36**	<0.001	0.41**	<0.001
Vitamin C (mg)	68.2 (42.1, 102)	118 (83.8, 159)	<0.001	73.0	0.29**	<0.001	0.45**	<0.001
Vitamin E (mg)	9.59 (7.70, 11.8)	12.5 (9.25, 16.1)	<0.001	30.3	0.31**	<0.001	0.48**	<0.001
Vitamin B6 (mg)	2.13 (1.71, 2.65)	3.24 (2.52, 4.22)	<0.001	52.1	0.33*	<0.001	0.27**	<0.001
Vitamin B12 (µg)	3.29 (2.60, 4.24)	3.68 (2.80, 4.76)	0.004	11.9	0.38**	<0.001	0.48**	<0.001
Folate (µg)	332 (271, 425)	325 (241, 398)	0.239	2.11	0.33**	<0.001	0.48**	<0.001
Retinol (µg)	336 (227, 431)	346 (253, 478)	0.075	2.98	0.36**	<0.001	0.42**	<0.001
Beta carotene equivalents (µg)	2756 (1900, 3826)	4301 (2813, 6097)	<0.001	56.1	0.26**	0.001	0.30**	<0.001
Sodium (mg)	2519 (2073, 2973)	2116 (1565, 2825)	0.001	-16.0	0.36**	<0.001	0.46**	<0.001
Potassium (mg)	2976 (2528, 3447)	3545 (2766, 4280)	<0.001	19.1	0.27**	<0.001	0.56**	<0.001
Magnesium (mg)	314 (275, 391)	367 (288, 462)	<0.001	16.9	0.42**	<0.001	0.71**	<0.001
Calcium (mg)	825 (685, 1049)	960 (750, 1237)	<0.001	16.4	0.41*	<0.001	0.52**	<0.001
Phosphorus (mg)	1418 (1223, 1581)	1492 (1198, 1840)	0.004	5.22	0.25**	0.002	0.44**	<0.001
Iron (mg)	11.5 (9.38, 13.6)	10.9 (8.67, 13.5)	0.383	-5.22	0.32**	<0.001	0.50**	<0.001
Zinc (mg)	10.1 (8.67, 11.4)	10.6 (8.33, 13.4)	0.025	4.95	0.26**	0.001	0.43**	<0.001
Selenium (µg)	59.1 (47.3, 72.6)	74.5 (55.1, 107)	<0.001	26.1	0.44**	0.001	0.47**	<0.001
Iodine (µg)	90.4 (73.2, 114)	66.8 (51.4, 85.1)	<0.001	-26.1	0.26**	<0.001	0.40**	<0.001

NZWFFQ, New Zealand Women's Food Frequency Questionnaire, 5d-FR, five-day estimated food record, SFA, saturated fat, PUFA, polyunsaturated fat, MUFA, monounsaturated fat

† Spearman's correlation coefficients *(r)*

‡Unadjusted raw dietary data

§ Adjusted for energy intake

¶ Mean and standard deviation

* p <0.05, two tailed test ** p <0.01, two-tailed test

Table 3.4 Median nutrient intakes from the NZWFFQ and 5d-FR, and correlation coefficients (n=126) among Pacific women

Nutrients	5d-FR median (25th, 75th percentile)	NZWFFQ median (25th, 75th percentile)	P-value	% difference	Correlation coefficients† Unadjusted *r*‡	p-value	Adjusted *r*§	p-value
Total energy (kJ)	8686 (6907, 9838)	10010 (8550, 13997)	<0.001	15.2	0.10	0.279	-	-
Protein (g)	77.3 (64.9, 97.6)	115 (91.3, 176)	<0.001	48.8	0.22*	0.015	0.33**	<0.001
Total fat (g)	88.5 (69.6, 107.2)	106 (85.3, 149)	<0.001	19.8	0.17	0.055	0.12	0.191
SFA (g)	34.3 (27.6, 42.7)	41.0 (32.4, 57.5)	<0.001	19.5	0.27**	0.002	0.16	0.77
PUFA (g)	11.6 (8.67, 14.6)	14.4 (10.7, 20.1)	<0.001	24.1	0.06	0.486	0.30**	0.001
MUFA (g)	33.7 (26.4, 40.3)	39.7 (30.1, 55.3)	<0.001	18.4	0.08	0.387	0.06	0.512
Cholesterol (mg)	265 (184, 3789)	378 (300, 581)	<0.001	42.6	0.32**	<0.001	0.42**	<0.001
Carbohydrates (g)	217 (163, 254)	254 (198, 351)	<0.001	17.1	0.09	0.308	0.29**	0.01
Sugars (g)	81.9 (63.7, 108)	117.4 (83.6, 166)	<0.001	43.3	0.16	0.079	0.30**	0.001
Dietary fibre (g)	18.5 (14.7, 22.6)	26.0 (19.8, 38.2)	<0.001	40.5	0.08	0.401	0.32**	<0.001
Alcohol (g)	0.02 (0.00, 0.20) 3.27 ± 11.1[d]	0.26 (0.03, 3.64) 2.92 ± 5.69[d]	<0.001	1200 -10.7[d]	0.47**	<0.001	0.39**	<0.001
Thiamin (mg)	1.21 (0.90, 1.61)	1.69 (1.22, 2.67)	<0.001	39.7	0.27**	0.002	0.20*	0.023
Riboflavin (mg)	1.63 (1.14, 2.06)	3.09 (2.07, 4.25)	<0.001	89.6	0.24**	0.008	0.13	0.138
Niacin (mg)	18.5 (14.6, 24.4)	30.6 (22.0, 43.4)	<0.001	65.4	0.23**	0.010	0.29**	0.001
Niacin equivalents (mg)	34.9 (27.9, 43.3)	52.0 (40.2, 71.7)	<0.001	49.0	0.24**	0.007	0.30**	0.001
Vitamin C (mg)	55.8 (35.6, 95.5)	145.7 (89.9, 209)	<0.001	161	0.20*	0.028	0.33**	<0.001
Vitamin E (mg)	8.58 (6.31, 11.0)	13.7 (10.2, 20.2)	<0.001	59.7	0.10	0.275	0.38**	<0.001
Vitamin B6 (mg)	2.22 (1.57, 2.86)	4.19 (2.86, 6.62)	<0.001	88.7	0.15	0.106	0.17	0.060
Vitamin B12 (µg)	3.70 (2.84, 4.59)	6.57 (4.33, 9.25)	<0.001	77.6	0.21*	0.016	0.12	0.179
Folate (µg)	237 (176, 335)	344 (242, 507)	<0.001	45.1	0.16	0.082	0.27**	0.003
Retinol (µg)	274 (174, 361)	429 (305, 590)	<0.001	56.6	0.18*	0.039	0.15	0.093
Beta carotene equivalents (µg)	1466 (745, 2491)	4041 (2505, 5891)	<0.001	176	0.32**	<0.001	0.32**	<0.001
Sodium (mg)	2778 (2194, 3518)	3060 (2501, 4508)	0.002	10.2	0.12	0.183	0.39**	<0.001
Potassium (mg)	2597 (1961, 3058)	3892 (2907, 5529)	<0.001	49.9	0.08	0.398	0.19*	0.031
Magnesium (mg)	264 (208, 321)	381 (292, 533)	<0.001	44.3	0.11	0.204	0.38**	<0.001
Calcium (mg)	588 (447, 838)	1068 (710, 1494)	<0.001	81.6	0.19*	0.190	0.28**	0.001
Phosphorus (mg)	1204 (957, 1456)	1780 (1330, 2492)	<0.001	47.8	0.15	0.092	0.29**	0.001
Iron (mg)	11.2 (8.53, 13.5)	13.8 (10.4, 20.4)	<0.001	23.2	0.15	0.085	0.20*	0.026
Zinc (mg)	9.51 (7.75, 12.0)	14.1 (10.8, 20.3)	<0.001	48.3	0.24**	0.006	0.26**	0.003
Selenium (µg)	56.8 (43.9, 83.2)	92.7 (69.6, 134.)	<0.001	63.2	0.23*	0.011	0.41**	<0.001
Iodine (µg)	82.7 (53.7, 121)	98.9 (54.4, 137)	0.53	19.6	-0.02	0.869	0.05	0.552

NZWFFQ, New Zealand Women's Food Frequency Questionnaire, 5d-FR, five-day estimated food record, SFA, saturated fat, PUFA, polyunsaturated fat, MUFA, monounsaturated fat

† Spearman's correlation coefficients *(r)*

‡ Unadjusted raw dietary data

§ Adjusted for energy intake

¶ Mean and standard deviation

* p <0.05, two tailed test ** p <0.01, two-tailed test

The level of agreement between nutrient intakes were estimated by comparing the 5d-FR with the NZWFFQ using cross-classification and the kappa statistic. Classification into correct, adjacent and extreme opposite quartiles of intake and the kappa statistic are shown in Table 3.5 for the total group, and independently for each group (Table 3.6 and 3.7). Cross-

classification agreement for the total group of women showed that participants classified into the same quartile ranged from 28.3% (iodine) to 39.1% (saturated fat) with an average of 33.0% **(**Table 3.5**).** The proportion within the same or adjacent quartiles ranged from 63.9% (iodine) to 78.2% (saturated fat) with an average of 72.0%. Gross misclassification into the opposite quartile ranged from 4.5% (sugar) to 11.2% (potassium) with an average of 7.9%.

Adjustment for energy improved classifications to 30.7% (iodine) to 47.4% (magnesium) with an average of 38.0% classified into the correct quartile, 65.6% (Vitamin C) to 87.5% (magnesium) with an average of 77.5% into the same and adjacent quartile and 1.0% (magnesium) to 9.8% (iodine) with an average of 5.41% into the extreme opposite quartile.

Using the weighted kappa statistic (κ**)** for unadjusted data showed most nutrients had a slight agreement (κ<0.20) and 8 nutrients had fair agreement (κ=0.21-0.40). Following energy adjustment most nutrients had a fair agreement, riboflavin, vitamin B6 and iodine had a slight agreement, and alcohol and magnesium had a moderate agreement (κ=0.41-0.60).

Table 3.5: Cross-classification and Cohen's Weighted Kappa Statistic of Unadjusted and Energy Adjusted NZ European and Pacific Women's Mean Daily Nutrient Intakes Derived from The NZWFFQ and 5d-FR (n=287)

	Unadjusted				***Energy-adjusted***			
Nutrients	Correct quartile (%)†	Adjacent quartile (%)‡	Extreme Opposite quartile (%)§	Weighted kappa statistic	Correct quartile (%)†	Adjacent quartile (%)‡	Extreme Opposite quartile (%)§	Weighted kappa statistic
Total energy (kJ)	31.4	40.8	8.7	0.16	-	-	-	-
Protein (g)	30.7	44.0	9.0	0.17	36.6	37.3	8.0	0.22
Total fat (g)	35.3	38.4	6.2	0.22	37.2	43.2	5.5	0.30
SFA (g)	39.1	39.1	5.6	0.29	39.1	37.6	5.6	0.28
PUFA (g)	34.6	33.5	6.9	0.16	39.4	38.4	2.8	0.31
MUFA (g)	30.4	42.9	5.9	0.18	35.5	40.4	5.5	0.25
Cholesterol (mg)	37.3	36.6	6.6	0.23	38.1	38.4	2.8	0.29
Carbohydrates (g)	34.6	39.0	6.2	0.21	42.5	40.2	3.1	0.37
Sugars (g)	32.8	38.6	4.5	0.20	37.7	41.5	4.5	0.30
Dietary fibre (g)	34.1	37.3	8.7	0.17	40.3	37.8	2.8	0.37
Alcohol (g)¶	-	-	-	-	43.9	41.1	1.4	0.42
Thiamin (mg)	34.6	38.7	8.7	0.19	34.5	42.2	7.3	0.23
Riboflavin (mg)	32.4	41.9	8.3	0.18	33.9	39.0	7.0	0.20
Niacin (mg)	38.3	35.2	5.9	0.25	34.2	45.0	6.6	0.25
Niacin equivalents (mg)	32.8	41.9	6.9	0.20	38.7	45.0	6.6	0.25
Vitamin C (mg)	30.7	40.5	9.8	0.13	37.6	39.8	5.9	0.27
Vitamin E (mg)	30.7	35.9	8.4	0.11	35.8	39.8	3.1	0.28
Vitamin B6 (mg)	34.6	37.3	8.7	0.18	37.7	27.9	8.3	0.16
Vitamin B12 (µg)	31.8	42.5	6.2	0.20	36.3	40.0	6.6	0.25
Folate (µg)	31.1	38.7	10.8	0.12	38.6	41.5	4.5	0.31
Retinol (µg)	30.6	41.9	9.0	0.15	34.9	37.7	4.2	0.22
Beta carotene equivalents (µg)	37.7	39.4	7.3	0.26	38.4	40.5	6.8	0.28
Sodium (mg)	32.8	38.8	8.0	0.17	41.8	35.8	4.5	0.32
Potassium (mg)	28.6	39.7	11.2	0.08	37.9	40.8	4.8	0.29
Magnesium (mg)	36.2	33.9	8.7	0.18	47.4	40.1	1.0	0.47
Calcium (mg)	30.7	40.7	7.3	0.16	39.6	40.4	5.5	0.31
Phosphorus (mg)	28.6	38.9	10.8	0.07	34.9	44.4	5.9	0.26
Iron (mg)	29.6	42.9	7.3	0.16	33.8	42.4	7.0	0.22
Zinc (mg)	31.8	41.2	9.1	0.16	38.8	33.8	7.3	0.23
Selenium (µg)	36.6	35.9	6.6	0.22	39.0	39.8	3.5	0.31
Iodine (µg)	28.3	35.6	10.5	0.05	30.7	38.4	9.8	0.12

NZWFFQ, New Zealand Women's Food Frequency Questionnaire; 5d-FR, 5-day estimated food record, SFA, saturated fat, PUFA, polyunsaturated fat, MUFA, monounsaturated fat

† Percentage of participants classified into the same quartile of intake

‡ Percentage of participants classified into the adjacent quartile of intake

§ Percentage of participants grossly classified into the opposite quartile of intake

¶ Alcohol was not divided into quartiles as >25% of participants consumed no alcohol (5d-FR)

Table 3.6 presents the cross classification and weighted kappa statistics for NZ European women. The percentage of NZ European women correctly classified into the same quartile ranged from 21.1% (sodium) to 50.3% (alcohol) with an average of 35.0% **(**Table 3.6**).** Classification into the same and adjacent quartiles ranged from 63.4% (sodium) to 90.7% (alcohol) with an average of 75.3%. Gross misclassification into the opposite quartile ranged from 0.6% (alcohol) to 10.6% (zinc) with an average of 5.8%.

After adjusting for energy intake, classifications improved, ranging from 33.5% (zinc) to 51.6% (carbohydrates and magnesium) with an average of 40.7% classified into the same quartile, 64.1% (beta-carotene) to 92.8% (carbohydrate) with an average of 81.0% into the same and adjacent quartile, and 0.6% (fibre and alcohol) to 9.3% (vitamin B6) with an average of only 3.6% into the extreme opposite quartile.

Most nutrients had a fair agreement using weighted kappa statistic with eight nutrients having a slight agreement and alcohol having a moderate agreement, overall ranging from 0.12 zinc (slight agreement) to 0.52 alcohol (moderate agreement). Following energy adjustment most nutrients had a fair agreement with slight agreement only for vitamin B6 and beta carotene, and a moderate agreement for eight nutrients (protein, total fat, carbohydrates, sugars, fibre, alcohol, potassium, magnesium).

The percentage of Pacific women classified into the same quartile was lower than the NZ European (Table 3.7), ranging from 21.4% (retinol) to 37.9% (polyunsaturated fat) with an average of only 31.0% correctly classified**.** Classification into the same and adjacent quartiles ranged from 61.8% (carbohydrate) to 74.8% (MUFA) with an average classification of 68.8%. Gross misclassification ranged from 4.4% (vitamin E) to 15.0% (iodine) with an average of 9.1%.

Adjustment for energy slightly improved the results to 23.8% (retinol) to 40.4% (zinc) with an average of 32.7% classified into the same quartile. 61.1% (iodine) to 78.4% (vitamin E) with an average of 71.2% into the same or adjacent quartile and 4.0% (vitamin E) to 11.9% (monounsaturated fat and iodine) with an average of 7.6% into the extreme opposite quartile.

The weighted kappa statistic had a fair agreement for beta carotene equivalents only all other nutrients had a slight agreement. Following energy adjustment, all nutrients improved except for thiamin, riboflavin, vitamin B12 and retinol while MUFA and iron remained the same. 15 nutrients remained with only slight agreement.

Table 3.6 Cross-classification and Cohen's Weighted Kappa Statistic of Unadjusted and Energy Adjusted NZ European Women's Mean Daily Nutrient Intakes Derived from The NZWFFQ and 5d-FR (*n*=161)

	Unadjusted				***Energy-adjusted***			
Nutrient	Correct quartile (%)†	Adjacent quartile (%)‡	Extreme Opposite quartile (%)§	Weighted kappa statistic	Correct quartile (%)†	Adjacent quartile (%)‡	Extreme Opposite quartile (%)§	Weighted kappa statistic
Total energy (kJ)	32.9	40.4	8.1	0.18	-	-	-	-
Protein (g)	37.2	35.4	4.4	0.24	39.0	40.4	5.5	0.30
Total fat (g)	37.9	41.7	4.3	0.30	47.9	41.2	1.2	0.48
SFA (g)	41.6	37.6	4.3	0.33	46.0	39.1	3.1	0.42
PUFA (g)	37.9	38.7	5.0	0.27	41.7	40.4	3.1	0.36
MUFA (g)	36.7	45.4	4.4	0.31	42.3	41.6	3.1	0.38
Cholesterol (mg)	36.7	40.4	3.1	0.28	41.5	43.6	2.5	0.39
Carbohydrates (g)	33.6	44.2	5.6	0.24	51.6	41.2	1.2	0.54
Sugars (g)	33.5	42.8	4.4	0.24	42.2	44.6	2.5	0.41
Fibre (g)	36.6	39.1	5.6	0.25	46.6	46.6	0.6	0.44
Alcohol (g)	50.3	40.4	0.6	0.52	44.7	37.8	0.6	0.48
Thiamin (mg)	31.0	42.3	7.5	0.17	40.3	38.5	3.7	0.32
Riboflavin (mg)	37.2	41.0	7.5	0.26	35.4	47.3	5.0	0.30
Niacin (mg)	39.1	35.4	4.9	0.27	36.0	44.9	4.9	0.29
Niacin equivalents (mg)	34.7	39.1	5.6	0.22	40.3	35.5	4.4	0.29
Vitamin C (mg)	34.1	43.0	9.3	0.21	39.8	37.9	5.6	0.29
Vitamin E (mg)	31.4	39.5	6.2	0.20	41.6	37.3	5.0	0.32
Vitamin B6 (mg)	36.7	33.5	6.2	0.20	37.2	30.4	9.3	0.16
Vitamin B12 (μg)	41.0	29.1	4.3	0.25	39.7	40.3	4.4	0.32
Folate (μg)	31.0	46.0	6.2	0.21	38.0	41.6	3.1	0.31
Retinol (μg)	33.6	43.0	6.8	0.22	39.2	37.2	3.8	0.29
Beta carotene equivalents (μg)	31.0	40.5	6.9	0.16	30.5	33.6	6.2	0.18
Sodium (mg)	21.1	42.3	3.7	0.17	36.0	44.2	3.1	0.30
Potassium (mg)	32.2	39.7	6.2	0.18	46.1	39.1	3.1	0.42
Magnesium (mg)	38.0	40.4	6.8	0.27	51.6	38.6	1.2	0.52
Calcium (mg)	36.7	42.9	5.6	0.28	38.6	41.8	3.1	0.32
Phosphorus (mg)	32.3	39.2	8.0	0.16	36.0	39.7	3.7	0.26
Iron (mg)	27.4	46.0	6.2	0.15	38.6	43.6	2.5	0.34
Zinc (mg)	28.6	44.1	10.6	0.12	33.5	46	3.7	0.27
Selenium (μg)	36.7	43.4	3.8	0.30	36.6	44.7	3.8	0.31
Iodine (μg)	37.3	32.9	6.8	0.20	41.6	33.6	3.7	0.30

NZWFFQ, New Zealand Women's Food Frequency Questionnaire; 5d-FR, 5-day estimated food record, SFA, saturated fat, PUFA, polyunsaturated fat, MUFA, monounsaturated fat

† Percentage of participants classified into the same quartile of intake

‡ Percentage of participants classified into the adjacent quartile of intake

§ Percentage of participants grossly classified into the opposite quartile of intake

Table 3.7 Cross-classification and Cohen's Weighted Kappa Statistic of Unadjusted and Energy Adjusted Pacific Women's Mean Daily Nutrient Intakes Derived from The NZWFFQ and 5d-FR (n=126)

	Unadjusted				***Energy-adjusted***			
Nutrient	Correct quartile (%)†	Adjacent quartile (%)‡	Extreme Opposite quartile (%)§	Weighted kappa statistic	Correct quartile (%)†	Adjacent quartile (%)‡	Extreme Opposite quartile (%)§	Weighted kappa statistic
Total energy (kJ)	30.1	36.4	9.5	0.09	-	-	-	-
Protein (g)	32.4	35.7	8.8	0.13	35.6	40.4	8.8	0.22
Total fat (g)	34.1	32.6	11.9	0.10	27.6	38.7	10.3	0.07
SFA (g)	30.9	41.1	8.0	0.16	30.0	38.8	8.8	0.12
PUFA (g)	37.9	35.7	5.0	0.03	34.8	37.2	8.8	0.18
MUFA (g)	36.7	38.1	4.4	0.04	28.5	35.6	11.9	0.04
Cholesterol (mg)	35.6	33.3	4.8	0.19	36.5	38.0	4.8	0.25
Carbohydrates (g)	28.4	33.4	9.6	0.04	34.1	40.4	7.2	0.21
Sugars (g)	31.0	34.1	7.2	0.10	29.3	41.2	6.4	0.14
Fibre (g)	31.6	31.8	11.1	0.07	26.2	47.4	6.4	0.27
Alcohol (g)¶	-	-	-	-	36.4	41.3	4.8	0.14
Thiamin (mg)	34.8	35.6	7.2	0.18	30.8	39.6	9.6	0.13
Riboflavin (mg)	25.5	46.7	7.2	0.12	26.8	39.5	9.6	0.07
Niacin (mg)	27.7	43.6	7.2	0.13	37.2	36.6	8.0	0.22
Niacin equivalents (mg)	34.0	38.7	13.5	0.14	38.0	35.6	7.2	0.22
Vitamin C (mg)	33.2	34.9	9.5	0.13	37.2	34.9	6.4	0.22
Vitamin E (mg)	30.8	37.2	10.3	0.10	28.5	49.9	4.0	0.22
Vitamin B6 (mg)	32.4	33.4	9.5	0.10	31.6	35.7	7.2	0.13
Vitamin B12 (µg)	34.1	32.6	7.2	0.14	27.0	40.3	7.2	0.09
Folate (µg)	25.3	41.2	9.6	0.05	28.4	43.4	8.8	0.13
Retinol (µg)	21.4	51.5	7.2	0.09	23.8	44.3	8.0	0.07
Beta carotene equivalents (µg)	37.2	37.3	7.2	0.23	38.8	38.0	8.0	0.26
Sodium (mg)	29.2	38.7	11.9	0.08	36.4	41.9	4.8	0.28
Potassium (mg)	28.5	37.3	10.4	0.07	34.8	33.4	9.6	0.14
Magnesium (mg)	27.7	38.1	11.1	0.05	38.0	35.7	5.6	0.25
Calcium (mg)	26.1	45.9	9.4	0.10	35.6	35.7	5.6	0.21
Phosphorus (mg)	32.4	37.2	11.9	0.12	34.0	42.0	8.8	0.21
Iron (mg)	33.2	37.3	8.8	0.16	31.6	40.3	8.8	0.16
Zinc (mg)	35.6	37.3	8.8	0.19	40.4	29.5	7.2	0.22
Selenium (µg)	31.7	37.2	8.8	0.13	36.4	41.1	4.8	0.27
Iodine (µg)	21.5	40.4	15.0	-0.061	25.4	35.7	11.9	-0.10

NZWFFQ, New Zealand Women's Food Frequency Questionnaire; 5d-FR, 5-day estimated food record, SFA, saturated fat, PUFA, polyunsaturated fat, MUFA, monounsaturated fat

† Percentage of participants classified into the same quartile of intake

‡ Percentage of participants classified into the adjacent quartile of intake

§ Percentage of participants grossly classified into the opposite quartile of intake

¶ Alcohol was not divided into quartiles as >25% of participants consumed no alcohol (5d-FR)

Bland and Altman mean differences between the NZWFFQ and 5d-FR and 95% LoA are presented in Table 3.8 for total group, NZ European and Pacific women. Mean differences indicate the NZWFFQ generally overestimated the 5d-FR in all groups except for alcohol and iodine in the total group. LOA for the total group were wide (e.g. energy intake 0.8MJ side of the mean) however, larger mean differences and wider 95% LoA were

observed for the Pacific women than the NZ European women. For example, the mean difference of the NZWFFQ overreported energy intake of the 5d-FR by 0.6MJ in the NZ European population vs 3.2MJ in the Pacific population and at the individual level, the variation in differences ranged 5.4MJ either side of the mean difference in 95% of the NZ European population and 10MJ in 95% of the Pacific population.

The Bland Altman plots demonstrate, as the average intake increases as the difference between the NZWFFQ and 5d-FR tend to increase. Generally, lower intakes were underestimated by the FFQ and larger intakes were overestimated excluding alcohol and iodine that are generally underestimated by the NZWFFQ as the average intake increases. For all nutrients except for alcohol (P=0.43) thiamin (P=0.45) and sodium (P=0.56) for the total group; Total fat (P=0.30), PUFA (P=0.15); MUFA (P=0.09); cholesterol (P=0.18); alcohol (P=0.12); folate (P=0.69), retinol (P=0.55) for the NZ European women; and iodine (P=0.60) for the Pacific women, the slope of the bias between the difference and mean intake of each nutrient were statistically significant ($P<0.05$), indicating a variation in agreement between methods and systematic bias for these nutrients. The mean error in intake of other nutrients (e.g. PUFA and MUFA for NZ European women) did not change with increased intake, despite the wider scatter with increasing mean intake that is sometimes observed.

Table 3.8: Bland-Altman 95% Limits of agreement between nutrient intakes derived from NZWFFQ and 5d-FR

	Total (n=287)		NZ European (n=161)		Pacific (n=126)	
Nutrient	Mean difference†	LOA‡	Mean difference†	LOA‡	Mean difference†	LOA‡
Total energy (kJ)	1760	-6473, 9994	626	-4793, 6045	3209	-6941, 13359
Protein (g)	27.2	-70.1, 124	7.85	-51.1, 66.8	51.9	-62.1, 166
Total fat (g)	13.7	-69.8, 97.2	3.83	-63.0, 70.7	26.3	-69.3, 122
SFA (g)	5.17	-29.3, 39.6	1.08	-27.6, 29.8	10.4	-28.0, 48.8
PUFA (g)	2.44	-11.5, 16.4	1.12	-11.2, 13.4	4.13	-11.1, 19.3
MUFA (g)	4.31	-27.3, 35.9	1.17	-23.8, 26.2	8.32	-28.8, 45.4
Cholesterol (mg)	48.6	-359, 456	-25.7	-334, 282	143	-300, 587
Carbohydrates (g)	43.7	-181, 268	20.1	-116, 156	74.0	-218, 366
Sugars (g)	33.6	-89.1, 156	21.6	-48.5, 91.8	49.0	-114, 212
Fibre (g)	7.24	-19.5, 34.0	4.24	-17.0, 25.4	11.1	-20.0, 42.1
Alcohol (g)	-0.82	-17.4, 15.8	-1.18	-16.2, 13.8	-0.35	-18.9, 18.2
Thiamine (mg)	0.29	-2.26, 2.84	-0.05	-2.33, 2.22	0.72	-1.90, 3.35
Riboflavin (mg)	1.10	-1.94, 4.13	0.49	-1.23, 2.21	1.87	-1.76, 5.50
Niacin(mg)	9.20	-21.0, 39.4	4.29	-12.0, 20.5	15.5	-22.9, 53.8
Niacin equivalents (mg)	14.1	-32.5, 60.6	5.69	-20.2, 31.6	24.7	-32.8, 82.2
Vitamin C (mg)	831	-218, 384	57.6	-98.0, 213	116	-295, 526
Vitamin E (mg)	4.39	-8.55, 17.3	2.71	-8.04, 13.5	6.53	-7.73, 20.8
Vitamin B6 (mg)	2.11	-3.97, 8.20	1.41	-2.52, 5.35	3.01	-4.69, 10.7
Vitamin B12 (µg)	1.99	-6.09, 10.1	0.69	-5.73, 7.12	3.64	-5.17, 12.4
Folate (µg)	54.2	-333, 442	-3.66	-312, 304	128	-302, 558
Retinol (µg)	85.3	-416, 587	8.66	-460, 478	183	-294, 661
Beta carotene equivalents (µg)	2297	-4046, 8640	1854	-4567, 8275	2863	-3226, 8952
Sodium (mg)	114	-2735, 2964	-277	-2120, 1567	614	-2923, 4150
Potassium (mg)	1077	-2202, 4356	578	-1613, 2769	1715	-2240, 5670
Magnesium(mg)	87.7	-232, 407	40.6	-199, 280	148	-220, 516
Calcium (mg)	294	-695, 1284	131	-581, 844	503	-633, 1639
Phosphorus (mg)	395	-1033, 1823	128	-805, 1062	735	-923, 2393
Iron (mg)	1.97	-11.5, 15.4	-0.34	-9.24, 8.56	4.91	-11.0, 20.9
Zinc (mg)	3.14	-8.83, 15.1	0.87	-6.50, 8.24	6.04	-8.11, 20.2
Selenium (µg)	32.7	-69.0, 134	23.8	-63.4, 111	44.1	-70.1, 158
Iodine (µg)	-31.0	-580, 518	-39.2	-304.3, 226	-20.4	-795, 754

NZWFFQ, New Zealand Women's Food Frequency Questionnaire; 5d-FR, 5-day estimated food record; LOA, limits of agreement.
†Mean difference = NZWFFQ – 5d-FR
‡ LOA= 95% limits of agreement

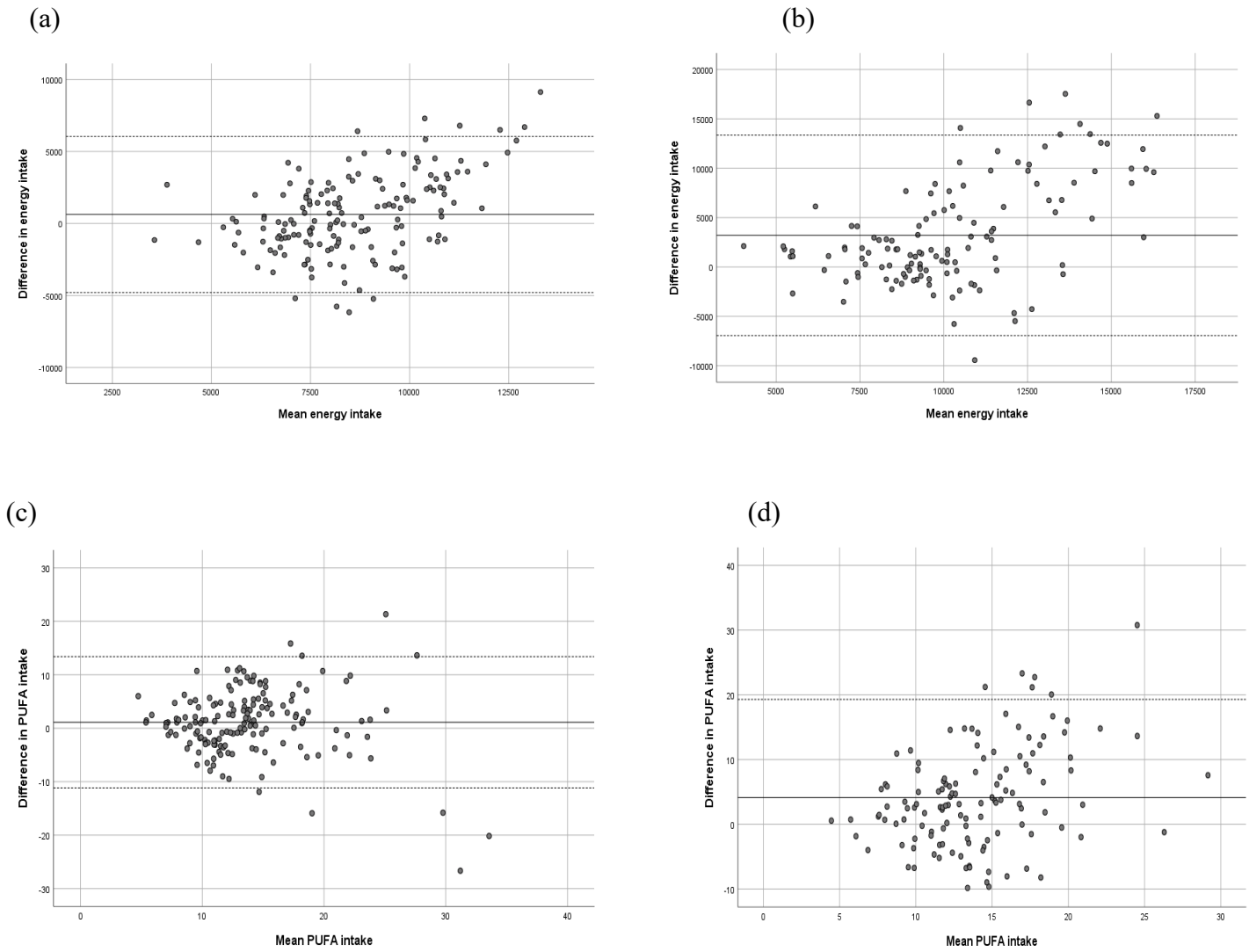

Figure 1 Bland-Altman plots of agreement between the NZWFFQ and the 5d-FR

Bland Altman plots show mean difference in intakes (solid line) and LoA; mean difference ± 2SD (dashed lines) for (a) NZ European energy intake (kJ) (n=161), (b) Pacific energy intake (kJ) (n=126), (c) NZ European polyunsaturated fatty acid (PUFA) intake (n=161), and (d) Pacific Polyunsaturated fatty acid (PUFA) intake (n=126).

3.5 Discussion

Only a few studies have validated nutrient intakes from FFQs in NZ women (Beck et al., 2018; Sam et al., 2012), and there have been no NZ studies in the last decade that have validated an FFQ independently in the Pacific population (Bell et al., 1999; Metcalf et al., 1997). In the present study we assessed the relative validity of a previously validated, semi-quantitative NZWFFQ designed to assess nutrient intake of a large group (n=287) of NZ European and Pacific premenopausal women living in New Zealand.

Median intakes of all macronutrients were estimated by the NZWFFQ and compared to the 5d-FR. All estimates differed by less than 20% of the 5d-FR except for sugars (32.6%), fibre (30.5%) and alcohol (2385%). However, for micronutrients only seven out of 20 differed by less than 20% (thiamin, folate, phosphorus, iron, zinc and iodine). This finding was similar to Beck et al. (2018) with all corresponding macronutrients except for dietary fibre within 20% of the food record, and three out of six micronutrients compared to the current study. When evaluated separately for ethnicity, 21 out of 31 (68%) nutrients had a median intake that differed by less than 20% of the 5d-FR in the NZ European women and seven nutrients (22.5%) in the Pacific women (total energy, total fat, SFA, MUFA, carbohydrates, sodium and iodine). However, When compared to the 5d-FR, the NZWFFQ was found to generally overestimate nutrient intakes, as has been reported previously (Beck et al., 2018; Metcalf et al., 1997; Sam et al., 2012; Sharpe et al., 1993; Zack et al., 2018). Differences in intake estimates between methods may be explained by the long list of food items on the NZWFFQ, where participants were asked to recall their frequency and calculate their intake of all food items over a lengthy period, a challenging task which may have led to the overestimation of actual intake. Iodine was the only nutrient significantly underestimated by the NZWFFQ when medians were compared. No studies evaluated, compared intakes of iodine, however a major dietary source of iodine in NZ comes from iodised salt. Alcohol was also underestimated when the NZWFFQ and 5d-FR were compared with means. This finding was similar to some studies (Beck et al., 2018; Kroke et al., 1999; Sam et al., 2012; Xinying et al., 2004) but not all (Hodge et al., 2000; Jackson et al., 2001). Some foods labelled as less ‘healthy’ such as salt or alcohol may influence the response of participants when recalling their intake on an FFQ. This may lead to the underreporting of these nutrients.

The NZWFFQ clearly, overestimated nutrient intake, and therefore is inappropriate to estimate absolute intake for individuals, however the main purpose of the NZWFFQ is to identify diet-disease associations rather than measure absolute intake. To do this, classifying individuals into different groups according to exposure of intake is more important (Masson et al., 2003; Willett, 1998) and hence correlation and cross-classification analyses were used to assess this. When correlations were assessed, correlation coefficients showed slight to acceptable validity for energy and nutrients and good validity for alcohol for the total group of women. Correlation coefficients fell in the range of 0.07 to 0.63, which were similar to those observed in other studies assessing nutrient intakes in the adult New Zealand population, ranging between -0.18 and 0.84 (Beck et al., 2018; Bell et al., 1999; Bolch, 1994; Metcalf et al., 1997; Sam et al., 2012; Sharpe et al., 1993). After adjusting for energy, correlation coefficients improved (0.17 to 0.61) for all nutrients except for alcohol and vitamin B6. All macronutrients and most micronutrients had correlations in the moderate to high ranges except for riboflavin, vitamin B6, zinc and iodine that were considered low. Lower correlations found for micronutrients may reflect the representation of food sources containing these nutrients in the NZWFFQ. FFQ's are limited, and therefore accurate representation of the diet depends on the foods commonly consumed in the food list (Willett, 1998). Overall, energy adjusted correlations demonstrate moderate to good validity with the larger number of the nutrients in the commonly observed range between 0.30 to 0.70 (Cade et al., 2002; Willett, 1998). These results compare well with other validation studies reporting adjusted correlations between -0.12 and 0.81 (Beck et al., 2018; Bell et al., 1999; Bolch, 1994; Hodge et al., 2000; Kroke et al., 1999).

When correlation coefficients were evaluated independently between ethnicities, correlations for Pacific and New Zealand European women differed substantially. Correlation coefficients ranged from 0.26 to 0.71 in the NZ European group vs -0.02 to 0.47 in the Pacific group. The NZ European correlations compared similarly to FFQ's in previous validation studies using diet records in New Zealand: (0.11-0.59 (Beck et al., 2018); 0.41-0.81 (Metcalf et al., 1997); 0.21-0.71 (Sharpe et al., 1993); Australia: 0.14-0.60 (Hodge et al., 2000); 0.22-0.78 (Xinying et al., 2004); Switzerland: 0.24-0.46 (Steinemann et al., 2017); U.S.A: 0.28-0.86 (Yuan et al., 2017). However, the Pacific group performed less well against these studies. When compared to the two other FFQ validation studies in New Zealand that evaluated the Pacific population independently, the Pacific group (-0.02-0.42) performed

similarly to Bell et al. (1999) (-0.03-0.48) and lower when compared to Metcalf et al. (1997) (0.36-0.56).

Similar to other studies, adjusting for energy intake further improved overall correlation coefficients for both NZ European and Pacific women. These ranged from 0.27 to 0.73 for the NZ European women and 0.05 to 0.42 for Pacific women. For the NZ European women, all the nutrients performed well, having moderate, large or very large correlations, except for vitamin B6 with a low correlation. In contrast, all nutrients for the Pacific women were classified with a low to moderate correlations. This shows the NZWFFQ performed better for the NZ European women than the Pacific women following energy adjustment. Higher correlations following energy adjustment indicate that energy intake is related to the variability in nutrient intakes. However, some nutrients in the Pacific group did not improve including fat: total, saturated, monounsaturated; alcohol, thiamin, riboflavin, vitamin B12 and retinol, suggesting an energy-independent source of bias such as misreporting may be present (Verger et al., 2017). Therefore, we could speculate that misreporting could have arisen from difficulty in estimating portion sizes or frequency of consumption of some foods rich in these nutrients, such as meat and poultry, on the NZWFFQ. Alcohol was one of the only nutrients that did not improve following energy adjustment in all groups (0.47 - 0.71 vs 0.39 – 0.69). However, alcohol had the highest correlation coefficient in all unadjusted groups. High correlations for alcohol have also been observed in other studies (0.77 (Hodge et al., 2000); 0.74 (Sam et al., 2012); 0.78 (Xinying et al., 2004); 0.56-0.81 (Metcalf et al., 1997)). It is worth noting however, that the NZWFFQ also identified 21% more participants that drink alcohol than the 5d-FR. Beck et al. (2018) reported the NZWFFQ overreported alcohol intake by 16% concluding that only four days of food intake recording may not be enough to identify high incidental intakes of alcohol on particular weekend days or social events. This may indicate that the NZWFFQ may be more accurate to measure nutrient intake of low to moderate consumption such as alcohol or other nutrients that are not consumed regularly, for example beta-carotene (Glovannucci et al., 1991; Serra-Majem et al., 2002).

Combining different methods of validation will improve the robustness of a validation study. While correlation coefficients can measure the association between two methods, cross-classification allows participants to be ranked according to low to high levels of intake. The ability of a tool to rank according to levels of intake may be more important when investigating diet-disease relationships. Masson et al. (2003) suggests that to minimise false-

negative diet-disease associations, multiple tests should be combined to validate nutrients. Masson recommends Spearman's correlations of 0.5 or more; with cross-classifications of at least 50% of subjects correctly classified and less than 10% misclassified, and a weighted kappa statistic of more than 0.4 to minimise false-negative diet-disease associations.

The total group classified more than 50% of all nutrients into the same or adjacent quartile (63.9 – 78.2%) and grossly misclassified less than 10% of all nutrients except for vitamin B12, sodium and calcium (4.5 – 11.2%). After accounting for chance agreement and degree of disagreement using the weighted kappa statistic, there were no unadjusted nutrients in the total group that had a weighted kappa >0.40 (0.05 – 0.29), indicating only fair agreement. After adjusting for energy intake however, all nutrients had improved classifications >50% (65.6 – 87.5%) and <10% were grossly misclassified into the opposite quartile (1.4 – 9.8%). After energy adjustment all but two nutrients (alcohol and magnesium) had a kappa statistic <0.40 (0.12 – 0.47 indicating moderate agreement for these two nutrients.

When considering the ethnicities independently, all nutrients in the NZ European group had classifications >50% in the same or adjacent category (63.4 - 90.7%) and all had <10% participants grossly misclassified into the opposite category except for zinc (10.6%) however, this improved following energy adjustment (7.3%). Eight nutrients in the NZ European group, namely total fat, SFA, CHO, sugars, fibre, alcohol, potassium and magnesium met requirements set by Masson to minimise false-negative diet-disease associations. All nutrients in the Pacific group had >50% of women classified into the same or adjacent quartile (61.8 – 74.8%) however, nine nutrients classified >10% participants into the opposite quartile. This improved following energy adjustment to three nutrients misclassified however, no nutrients had a kappa statistic >0.4 (-0.10-0.28).

Comparing cross-classification of nutrients in validation studies is difficult as variation between parameters into tertiles, quartiles and quintiles differ between studies. One New Zealand study using the NZWFFQ has classified women (n =110) into quartiles (Beck et al., 2018). This study classified a similar percentage of women into same and adjacent quartiles, and opposite quartiles for most nutrients as the present study. However, some nutrients were better classified in the NZ European population in the current study such as carbohydrate (92.8% vs 77.3% classified correctly, and 1.2% vs 3.6% misclassified

respectively); sugars (93.2% vs 80.9% classified correctly, and 0.6% vs 5.5% misclassified and folate (79.6% vs 69.1% classified correctly, and 3.1% vs 7.3% misclassified. When compared to the Pacific population the current study performed less well in most nutrients except for folate that performed similarly to Beck et al. (2018) (69.1% vs 71.8% classified correctly and 7.3% vs 8.8% vs misclassified respectively). Similar results were found in another NZ study using quartiles (Sam et al., 2012). The total group in the NZWFFQ found similar proportions of participants classified into same and adjacent quartiles when compared to Sam et al. (2012) (average 72% vs 75.3% respectively) and similarly increased following energy adjustment (average 77.5% vs 77.9% respectively).

Bland-Altman analysis has been recommended as a more reliable method to assess validity than other methods such as correlation coefficients (Bland & Altman, 1986). These, as a measure of validity are regarded as misleading as they measure the strength of the linear association between the two methods and can only detect random error, rather than absolute agreement of the two measurements. Systematic biases can however be observed in the Bland-Altman analysis (Ludbrook, 1997), and is often recommended to use as a further complementary method of FFQ validation techniques, and should be used alongside correlation and regression analysis (Cade et al., 2002). Systematic bias was evident in the Bland-Altman analysis with the NZWFFQ differing from the 5d-FR in all nutrients except for alcohol and thiamin and the NZWFFQ over-estimating the 5d-FR in all nutrients except thiamin and iodine. The Limits of Agreement were very wide for the total group with a variation of 8.2MJ either side of the mean difference. These intervals are too wide to suggest the NZWFFQ is appropriate to assess energy intake in individuals in the total group. Wide LoA have previously been reported for energy in Xinying et al. (2004) and Hodge et al. (2000) however were smaller than observed in the present study (5MJ and 4MJ respectively).

When compared independently between ethnicities, mean differences and LoA performed differently. For example, the mean difference in energy intake from the NZWFFQ in the total group was 1,760kJ however, between ethnicity the energy intake was five times higher in the Pacific group than that of the NZ European group (626kJ vs 3209kJ) indicating a greater extent of bias in the Pacific group than the NZ European group. Bias was present in each group with all nutrient intakes estimated by the NZWFFQ differing from the 5d-FR except for five nutrients in the NZ European group (thiamin, riboflavin, vitamin B12, iron

and zinc) and all but one in the Pacific group (alcohol). Mean differences were comparable in other studies to the NZ European group however, were much larger in the Pacific group (e.g. mean difference of carbohydrate was 20 for NZ European and 74 for Pacific in this study vs 32, 31 and 44 for Hodge et al. (2000), Xinying et al. (2004) and Verger et al. (2017), respectively).

LoA were wide for both groups, however, the NZ European women performed similarly to that of Xinying et al. (2004), Hodge et al. (2000) and Verger et al. (2017). Again, the Pacific women had substantially wider LoA compared to these studies, however, performed similarly for both mean differences and LoA for carbohydrate, fat and protein to a New Zealand Pacific population (Bell et al., 1999). Bland-Altman plots (figure 1 (a) and (b)) for energy indicate over-reporting of dietary intake as dietary consumption increased. This was consistently observed in groups, however was not significant for all nutrients. A similar observation has previously been reported in the NZWFFQ (Beck et al., 2018).

Overall, The NZWFFQ overreported most nutrient intakes when medians were compared, suggesting the NZWFFQ is not appropriate for estimating nutrient intake of individuals. However, as FFQ's are commonly designed for ranking nutrients rather than assessing absolute nutrient intakes of individuals, cross-classification may be more appropriate to use. Cross-classification showed the NZWFFQ was useful in ranking participants according to nutrient intake with more women ranked into the correct quartiles of intake in the NZ European group than Pacific. Statistical analysis improved following energy adjustment for both correlations and cross-classifications and energy-adjusted correlations and cross-classifications performed well against other FFQ validation studies for NZ European women and worse for Pacific women. Bland-Altman analysis performed differently between ethnic groups with greater systematic bias evident in the Pacific group than the New Zealand European group. Mean differences varied between methods for most nutrients in both populations, however, this was comparable with other studies in the NZ European group (Hodge et al., 2000; Verger et al., 2017; Xinying et al., 2004). The reported LoA were also similar to these studies, however were still wide for all groups indicating discrepancies between methods e.g. LOA for saturated fat for NZ European -.27.6- 29.8; Pacific -28.0-48.8; vs -21.0-23.4 and -25.5-21.5 Hodge et al. (2000) and Hodge et al. (2000).

While there are many challenges associated with dietary validation, there were a number of strengths in this study that must be highlighted. One of the main strengths is the overall sample size of each population group. Overall, the study included 287 participants in total, 161 NZ European and 125 Pacific women. This exceeded the 50 to 100 or more participants recommended for validating dietary methods and was appropriate to compare differences between populations with the cross-sectional design of the study (Cade et al., 2002), of which 44% were Pacific women. This was a key strength as previous studies validating nutrient intakes in the New Zealand population have predominantly included NZ European participants with few Pacific or Maori (Beck et al., 2018; Sam et al., 2012). This is of particular importance as the performance of an FFQ has previously been shown to differ in Māori and Pacific when compared to the New Zealand European population (Bell et al., 1999); Metcalf et al. (1997). In Metcalf et al. (1997) lower correlation coefficients were observed in the NZ European population than the Pacific and Māori, although the Pacific and Māori population were found to underestimate their energy intake on a 3-day food record and the NZ European population were more likely to underestimate on a FFQ. Energy intake was also underreported in a New Zealand Samoan population (Bell et al., 1999; Metcalf et al., 1997).

The NZWFFQ was a self-administered online FFQ. While interviewer administered FFQ's are preferred (Cade et al., 2002), the online nature of the FFQ ensured all answers were completed. The administration of the NZWFFQ was assessed two weeks following the 5d-FR and the food record was collected on five non-consecutive days as suggested by Cade et al. (2002), and met the recommended three to seven days of recording for validation studies (Ortega et al., 2015). Finally, four statistical methods were used to assess validity including Bland-Altman analysis that improve the credibility of results.

The study contained several challenges. While the diet record is commonly used as a reference tool in validation as it is considered to be the gold standard of other dietary assessment methods (Ortega, 2015), it however, is still not free of error. Although, exact portion sizes are recorded when eaten which enhances the accuracy of the portion size estimates and lowers the reliance on memory, diet records require participants to be highly motivated and literate. The process of recording diet itself may induce changes in dietary behaviour (Ortega, 2015) which has been reported in the Pacific population (Bell et al., 1999). The participant burden of five days of recording may have reduced the compliance of

the Pacific population and could have led to underreporting. This has previously been reported in the Samoan population using a 7-day weighted food record, when even after reducing the number of consecutive recording days, underestimation could not be overcome (Bell et al., 1999). Another method with a lower participant burden, such as multiple 24-hour recalls, may be more ideal as a reference tool in this group.

As for the FFQ, the low agreement between the NZWFFQ and 5d-FR may in part be explained by the semi-quantitative design of the FFQ. Quantification of portion sizes are difficult for individuals. Semi-quantitative questionnaires provide both portion size estimates and frequency consumed which is noted by Cade et al. (2002) to be cognitively challenging, especially when the subject does not consume the portion size of the food item specified in the FFQ. As the NZWFFQ requires all questions to be completed, participants may have selected a portion size category different to that of their true intake if food items or portion size estimates are not understood by the participant (Cade et al., 2002; FAO, 2018). Using a trained interviewer to support the participants during the completion of the NZWFFQ may be appropriate in the Pacific population.

This is one of the few studies validating nutrient intake in New Zealand women (Beck et al., 2018; Bolch, 1994) and the first to validate NZ European and Pacific women independently. This validation study supports the suggestion that the NZWFFQ should be adjusted for energy to interpret nutrient intakes (Beck et al., 2018). The application of different statistical approaches for analysis suggests the NZWFFQ is acceptable for use in the total PROMIsE study population and is valid for use in the NZ European population to rank individuals by their nutrient intake. Improvements in the administration of the NZWFFQ and exploring the use of an alternative reference tool may however need to be further evaluated to improve outcomes for use among Pacific women living in New Zealand.

Chapter 4: Conclusion

4.1 Overview and Achievement of Study Aims and Objectives

To our knowledge, this has been the first food frequency questionnaire in New Zealand that has independently assessed the relative validity of nutrient intakes in both Pacific and New Zealand European women. The importance of validating FFQs before drawing conclusions about how dietary intake influences health and disease is well recognised (Lee & Nieman, 2007; Margetts & Nelson, 1997; Willett, 2012). The performance of FFQs can differ in different populations and must be validated for use in their intended population (Cade et al., 2004). Within the NZ population there is a disparity between the prevalence of chronic disease in NZ European and Pacific ethnicity groups (Ministry of Health, 2017a). Diet plays a major role in many of these diseases (World Health Organization, 2003), and therefore, it is critical to assess diet independently for these ethnic groups. While the NZWFFQ has previously been validated in a New Zealand population of women, it was not validated in different ethnicities separately nor did it obtain a sample size sufficiently representative of the Pacific population to do so. In the present study, the aim was to evaluate and validate a semi-quantitative food frequency questionnaire (NZWFFQ) in 18-45-year-old pre-menopausal adult NZ European and Pacific women participating in the PROMIsE study, living in the greater Auckland area of New Zealand. To achieve this, a group of statistical techniques were used including: Wilcoxon Signed rank test-, correlation coefficient-, cross-classification-, and Bland-Altman analyses to evaluate nutrient intakes of all women, as well as ethnicity groups independently. Findings from each test will be described below in terms of the study objectives as discussed in Chapter 1.

Main Findings and Concluding Remarks

Study objectives:

1. To determine and compare the energy and nutrient intakes derived from the NZWFFQ and the 5-day estimated food record reported by premenopausal Pacific and New Zealand European women participating in the PROMIsE study, both as a group and independently.

When median intakes were compared to an estimated 5-day food record, the NZWFFQ overestimated energy and most nutrients for the total group with overestimation generally greater in micronutrients. Overestimation is common with the increased burden of long FFQs (including many foods), as was the case with the 220-item NZWFFQ. Differences in median energy and nutrient intakes in the Pacific population were higher than the NZ European population.

2. To evaluate and validate the NZWFFQ against the 5-day estimated food record in all premenopausal Pacific and New Zealand European women participating in the PROMIsE study.

The first step assessing relative validity was to compare the daily amount of nutrients consumed as estimated by both the NZWFFQ and 5d-FR in the total population group of 287 NZ European and Pacific women. The findings from this study found the NZWFFQ correlated moderately well with the 5d-FR and performed well to rank participants by nutrient intake after adjusting for energy intake, however only fairly well after accounting for chance agreement. Lower correlations such as those seen in micronutrients: riboflavin, vitamin B6, zinc and iodine may arise from exclusion of rich food sources of these nutrients due to the limited number of foods present in the food list of the NZWFFQ, however, both correlations and cross-classification still performed similarly to other comparative studies (Beck et al., 2018; Hodge et al., 2000; Sam et al., 2012; Xinying et al., 2004; Yuan et al., 2017). Bias was also observed at both individual and group level between methods for most nutrients shown by mean differences and wide limits of agreement respectively. The NZWFFQ differed from the 5d-FR in all nutrients except for alcohol and thiamin and the range of intakes were too wide to suggest the NZWFFQ is appropriate for use for assessing nutrient intakes of individuals. The current study found overall, the NZWFFQ was a reasonably valid tool for measuring nutrient intake after adjustment for energy in all women participating in the PROMIsE study.

2.1 To determine if the NZWFFQ is a valid tool to assess the nutrient intakes of premenopausal adult New Zealand European women.

The relative validity was determined by comparing both the frequency and daily amount of nutrients consumed as estimated by the NZWFFQ and 5d-FR in the NZ European group of

161 NZ European women. The findings from the study found the validity of the NZWFFQ were well correlated and performed well to rank individuals by nutrient intake after adjusting for energy intake, and had a moderate to fair agreement after accounting for chance. Six macronutrients (total fat, SFA, CHO, sugars, fibre and alcohol) and two micronutrients (potassium and magnesium) met recommendations to minimise false-diet disease relationships. Improvement after energy adjustment by 6% in correlation coefficients and cross-classification with an average improvement in women correctly classified into quartiles by 0.13% reflects the significant contribution energy intake has in the variability of nutrient intakes in these women. Bias however, was observed at both individual and group level between methods for most nutrients however, this was comparable to other similar studies (Hodge et al., 2000; Verger et al., 2017; Xinying et al., 2004). The current study found the NZWFFQ was a valid tool for measuring nutrient intake in the NZ European population.

2.2 To determine if the NZWFFQ is a valid tool to assess the nutrient intakes of premenopausal adult Pacific women.

The relative validity was determined by comparing both the frequency and daily amount of nutrients consumed as estimated by the NZWFFQ and 5d-FR in the sample group of 126 Pacific women. The findings from the study found the NZWFFQ correlated only slightly with the 5d-FR both before and after adjusting for energy. However, it performed well to classify individuals by nutrient intake. Only small improvements in correlation coefficients (average increase in 0.13) and classification (average increase in 1.7% participants correctly classified) were observed after adjusting for energy were observed. This suggests sources of systematic bias unrelated to energy intake may be present in this group, for example difficulty in estimating portion sizes and frequency of consuming foods listed in the NZWFFQ. When accounting for chance agreement, the tool performed slightly for ranking participants. Significant bias was also observed at the individual and group levels between methods for most nutrients, with greater mean differences and variation in intakes compared to other studies (Hodge et al., 2000; Verger et al., 2017; Xinying et al., 2004). The current study found overall for Pacific women, the NZWFFQ did not perform well against a 5d-FR for assessing nutrient intakes.

Overall, the NZWFFQ overreported intake of nutrients when compared to the 5d-FR, and the tool performed better after adjusting for energy intake. The NZWFFQ performed well to rank individuals by their nutrient intake in the total group however, differed in performance between ethnic groups. The tool performed well for the New Zealand European population but less so for the Pacific population.

4.2 Strengths and Limitations

There is no single method for assessing dietary intake perfectly. All dietary assessment methods have a number of challenges including study population, design of dietary tools and the accuracy of the reference method. Within the context of a validation study, the following aspects and their potential effects on the study will be discussed: the study population, sample size, food frequency questionnaire design, reference method, administration, reproducibility and statistical analysis.

Study population

Food frequency questionnaires must be validated in a representative sub-sample of the population including: gender, age and ethnicity (Cade et al., 2002). The current study included the total number of participants in the main study population who completed both the NZWFFQ and 5d-FR, and therefore was representative for use in the PROMIsE study population.

The participants recruited in the study were all volunteers. This may be a limitation in the representativeness of this study sample to the NZ population, as volunteers may be more highly motivated and therefore may respond differently to a questionnaire than non-volunteers that may therefore, provide more accurate responses (Cade et al., 2002). The study recruiting process included advertising in newspapers and magazines that may have influenced inclusion of a more motivated participant group than the general population, however due to distance and cost barriers for some Pacific participants, effort was taken to include some participants by providing transport options, thereby including some participants that may otherwise not have taken part.

Sample size

A major strength of the current study was the sample size. Cade et al. (2004) recommend that a sample size of 100 or more is preferable to provide better estimates of validity. The current study exceeded this with a sample size of 287 participants including 161 NZ European and 126 Pacific women. The sample size of both populations is large enough to be used for validating dietary methods independently. This is the largest sample of a Pacific ethnic group found in a validation study to date, and therefore a key strength of the study (Bell et al., 1999; Metcalf et al., 1997).

Food frequency questionnaire design

Challenges related to FFQ's arise from errors in misreporting due to a number of factors associated with the design of the FFQ. Length of the food list and quantification of portion size estimates can influence validity. Accuracy of responses may reduce towards the end of FFQ's due to an increase in participant boredom and fatigue (Cade et al., 2002). The 220-item NZWFFQ took 25 minutes to complete. Questions at the latter end of the NZWFFQ included questions regarding adding salt during cooking and takeaway foods, that could have contributed to the lower correlations of some nutrients such as iodine, total fat, saturated fat, vitamin B6 and vitamin B12 that were predominantly lower in the Pacific group. Additionally, the NZWFFQ used a semi-quantitative design, requiring participants to describe their own portion size. This poses cognitive challenges for many participants and may reduce the variation in intake as portion size questions may encourage participants to include a standard portion size given rather than quantifying actual intake. Further challenges are faced when frequency of intake questions are combined with portion size questions as in the NZWFFQ and foods commonly consumed by participants are not in the specified portion size specified in the FFQ (Cade et al., 2002). This may result in misreporting from participants choosing the incorrect frequency of intake. This may have resulted in the overestimation of energy and nutrients in the NZWFFQ, especially seen in the Pacific population. Additionally, perception of portion size may also differ depending on the population. - overweight participants may underestimate their own portion sizes (Margetts & Nelson, 1997). While both normal weight and obese participants were present in the validation study, BMI categories were not validated separately and therefore, this observation could not be determined.

Reference method

There is no perfectly accurate dietary assessment method as bias is present in every measurement of dietary intake (Cade et al., 2002; Margetts & Nelson, 1997). Choice of a reference method depends on the validity of the method itself where a superior method with uncorrelated errors to the test tool should be the preferred choice for a reference method. The gold-standard dietary reference tool is the weighed food record, although the use of a weighed food record in the Pacific population has previously been questioned by Bell et al. (1999). They reported underestimation of the 7-day weighed food diary, and authors noted that subjects had not used the food scales or measuring equipment provided. It is well documented that weighing increases participant burden and may result in modification of dietary intake (Ortega et al., 2015). As a method without the added participant burden of weighing food, the use of an estimated food record may be more appropriate in this population. Therefore, using the estimated food record as the method of choice in this study is another strength of this study.

Food records have been preferred for use as a reference tool in a wide number of other studies as it has the least correlated errors with the FFQ (Willett, 1998). However, two main considerations must be made when using food records. The first consideration is the number of days the dietary assessment was recorded (Margetts & Nelson, 1997). To optimise data quality and minimise participant burden, three to seven days has been recommended as the ideal number of recording days. This was consistent with the present study including five days of records. The diet record was also administered on non-consecutive days which had been suggested to improve the representation of the diet (Ortega et al., 2015).

The second consideration is the food composition database. To minimise errors, the same database for the food record and test methods should be used. FoodWorks version 8 was used as the main software for nutrient analysis as it uses the New Zealand food composition database, NZ FOODfiles (Plant & Food Research and MOH, 2014), followed by Australian databases: AusFoods 2015, and AusBrands 2015. As new foods are continuously becoming available for the consumer, all current food products are not necessarily available within this database. To account for this a “new food” was added that matched the nutritional information panels (NIP). Some NIP from food packaging were provided by participants for

certain products consumed during the completion of the 5d-FR. Other food items not present in the database were substituted with specific substitutions agreed between researchers entering food data.

Administration

A strength of the study is the sequence that was used to administer both the test method (NZWFFQ) and the reference method. It is recommended that the reference method is administered prior to the test method and each method should assess the same period of time e.g. one month (Cade et al., 2002). The NZWFFQ in this study was administered within two weeks following the 5d-FR and was designed to assess the previous month of recording. However, a limitation was that the estimated-FR recorded five days of dietary intake across nine days, which meant that the test and reference method only partially assessed the same period.

Another limitation of the study relating to administration was the self-administered method of the NZWFFQ. It is preferred that FFQ's are interview administered (Cade et al., 2002), however this depends on resources available for data collection. Alternatively, self-administered questionnaires may be used where cross-checking can be undertaken soon after the questionnaire has been completed, to check for completeness. The present study used an online-format that required all sections to be completed before continuing on with the questionnaire. A researcher was also present during data collection to assist participants when needed. All validation studies reviewed in the literature review were self-administered, which reflect the practicalities and resources required to administer an FFQ using a trained interviewer. Furthermore, Caan et al. (1999) found agreement was improved when a trained interviewer probed for correct answers on an interview administered FFQ. The use of a trained interviewer in the present study could have further improved the agreement on the FFQ.

Reproducibility

It is possible for a study to provide an accurate estimate of intake, yet little precision. The present sample did not assess reproducibility; the ability of the same sample to give the same answer after repeat administrations under the same conditions. The NZWFFQ was assessed in one administration however the data collection period across the study was collected over two occasions across two weeks. Although reproducibility is assessed across repeat

administrations, the timeframe and resourcing available in this study did not allow for reproducibility testing. The two data collection periods were only two weeks apart, and therefore did not meet recommendations of being four to eight weeks apart to preclude participants remembering and replicating previous answers due to too short time intervals (Block & Hartman, 1989; Cade et al., 2004).

Statistical analysis

Cade et al. (2002) suggests a range of statistical methods should be used to improve the robustness of FFQ validation studies including correlation, regression, Bland-Altman, Kappa statistic sand paired t-tests or Wilcoxon signed-rank sum test. This was a strength in the validation study in which we used four popular methods to assess instrument validity, including Wilcoxon-signed rank test, correlation-, cross-classification- and Bland-Altman analyses.

4.4 Recommendations

There are a number of aspects within this study that could have been done differently if the study was repeated. These are as follows:

- Assess the validity of the NZWFFQ within BMI categories separately e.g. 18.5 - 24.9 kg/m^2, >30kg/m^2
- Use an interviewer-administered method of administration in the Pacific population to reduce error associated with portion size estimation on the NZWFFQ
- Assess the validity of the NZWFFQ in foods, portions sizes and food groups consumed to determine valid diet-disease associations between these groups
- Collect food record data on more spread-out days to meet the same reference range as the NZWFFQ of one month e.g. one day per week over 1 month

Recommendations for future research

- Assess the validity in other sub-populations including NZ European and Pacific men, as well as Maori and Asian ethnicity groups living in New Zealand.

- Use multiple 24-hour recalls as a reference method in FFQ validation studies in the Pacific population
- Consider the use of biochemical measurements of intake as an external measure of validity.
- Assess the reproducibility of the NZWFFQ in the NZ European and Pacific group separately.
- Adjust for energy when using the NZWFFQ to assess nutrient intakes in the NZ European and Pacific populations.

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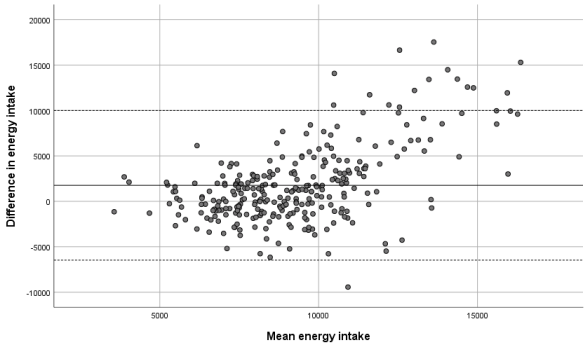
Appendices

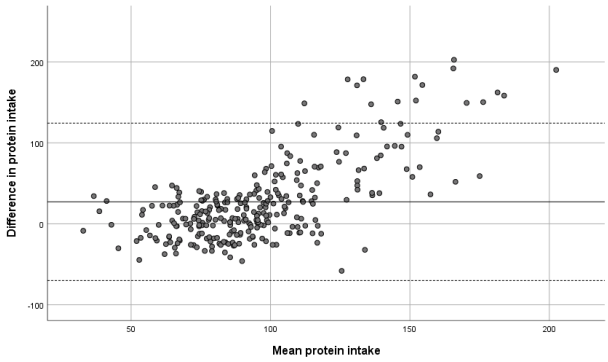
Appendix A: Supplementary Results

Figure A.1 Bland Altman Plots of relative validity for dietary intake from the NZWFFQ and 5d-FR

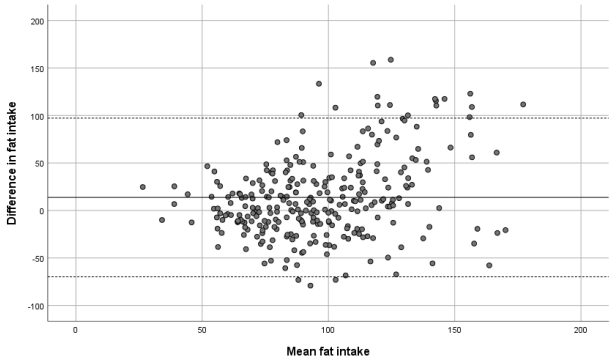
Total group



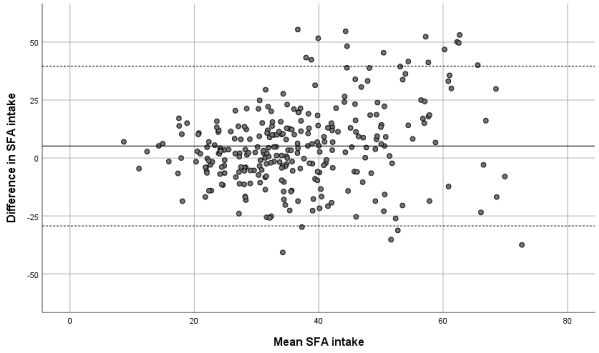
(A): Bland-Altman plot of energy intake



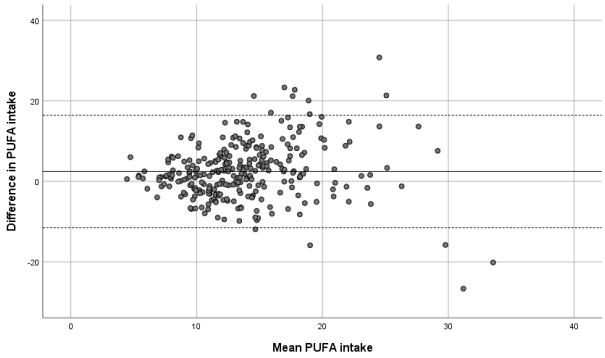
(B): Bland-Altman plot of protein intake



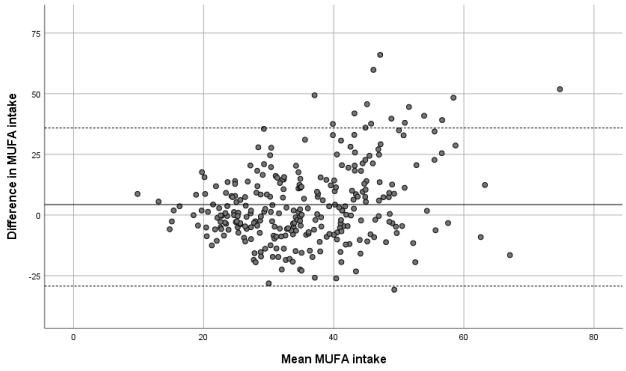
(C): Bland-Altman plot of fat intake



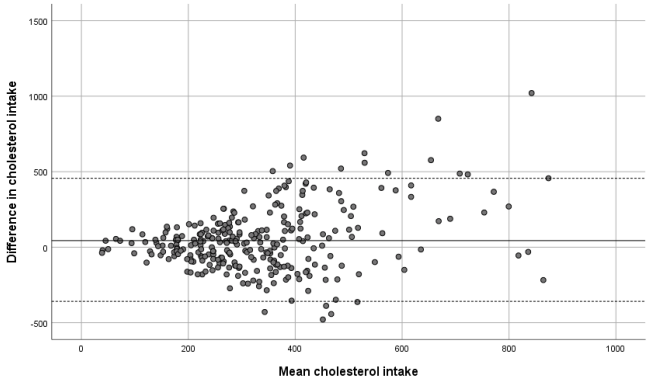
(D): Bland-Altman plot of Saturated fat intake



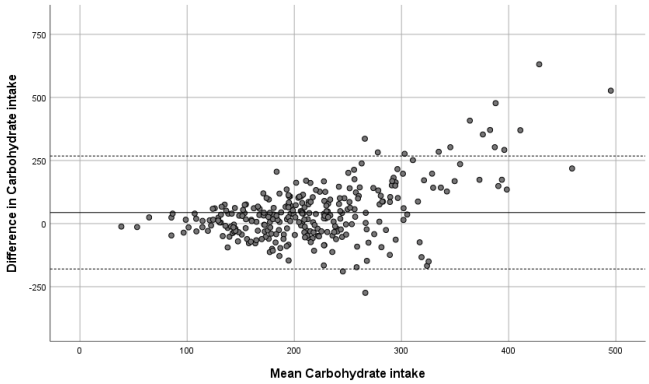
(E): Bland-Altman plot of Polyunsaturated fat intake



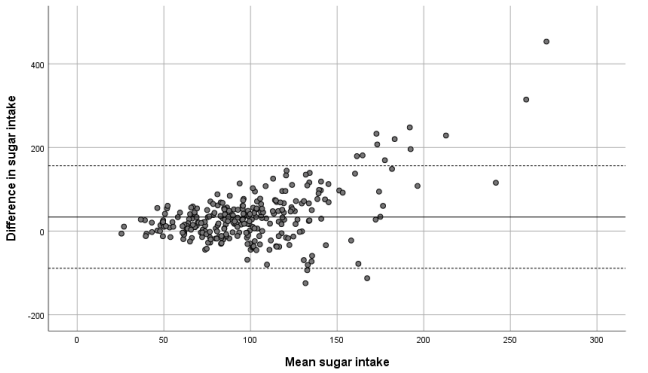
(F): Bland-Altman plot of monounsaturated fat intake



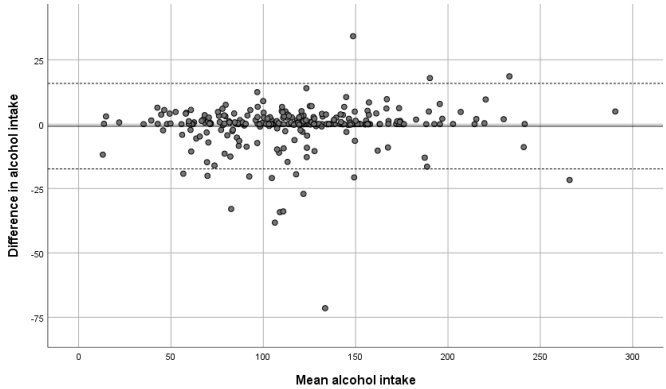
(G): Bland-Altman plot of cholesterol



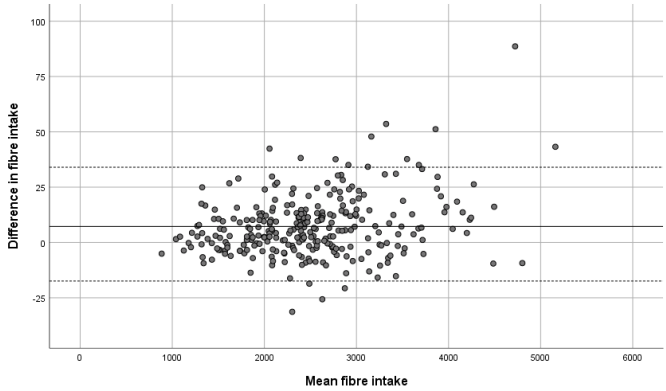
(H): Bland-Altman plot of Carbohydrate



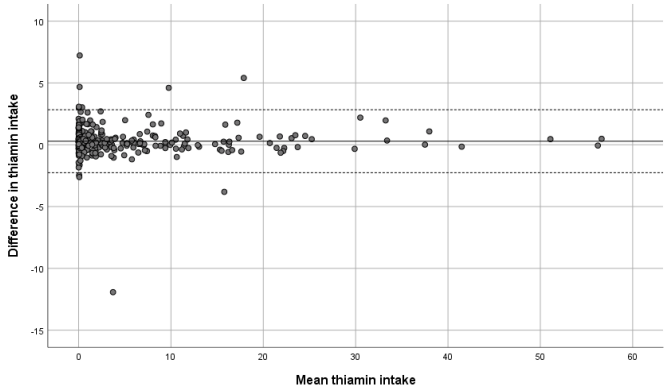
(I): Bland-Altman plot of Sugar



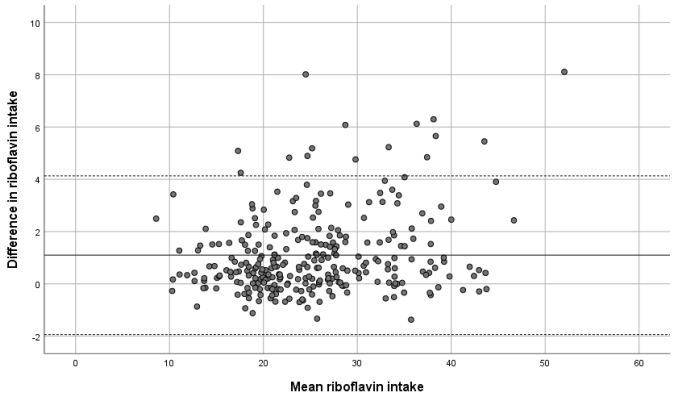
(J): Bland-Altman plot of alcohol intake



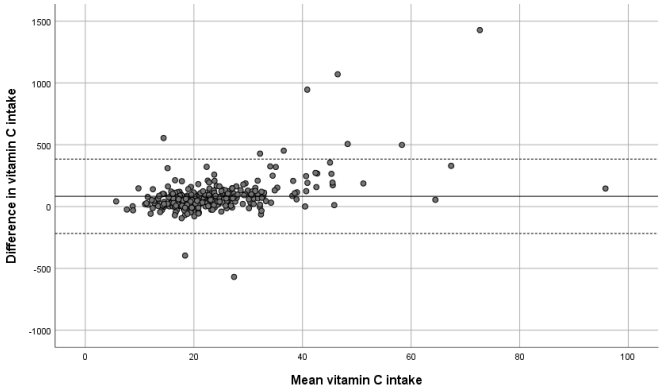
(K): Bland-Altman plot of fibre intake



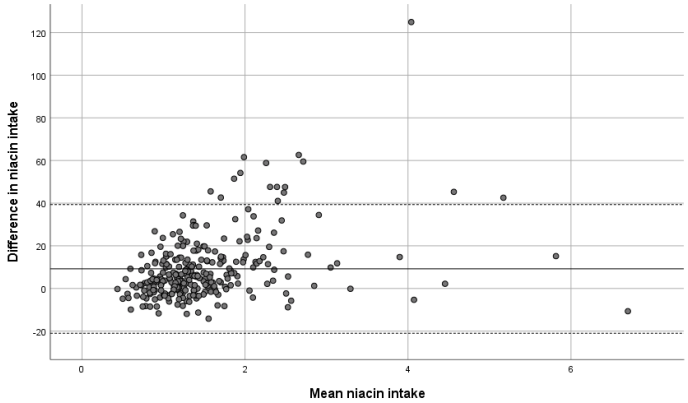
(L): Bland-Altman plot of thiamin intake



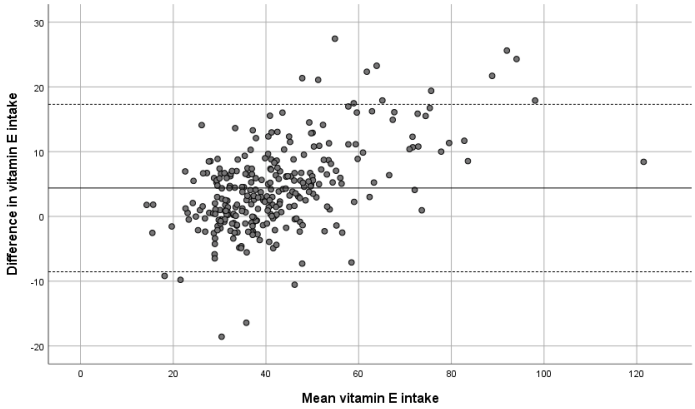
(M): Bland-Altman plot of riboflavin intake



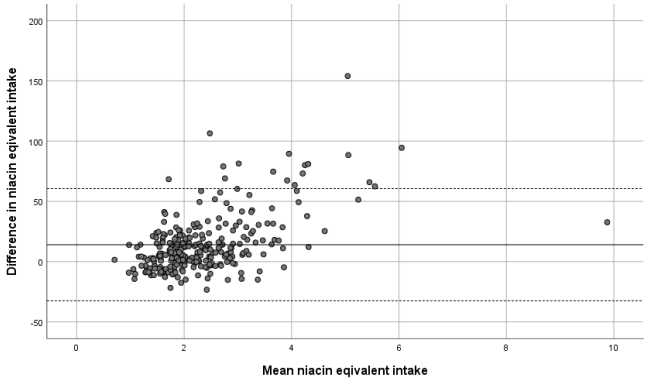
(P): Bland-Altman plot of vitamin C intake



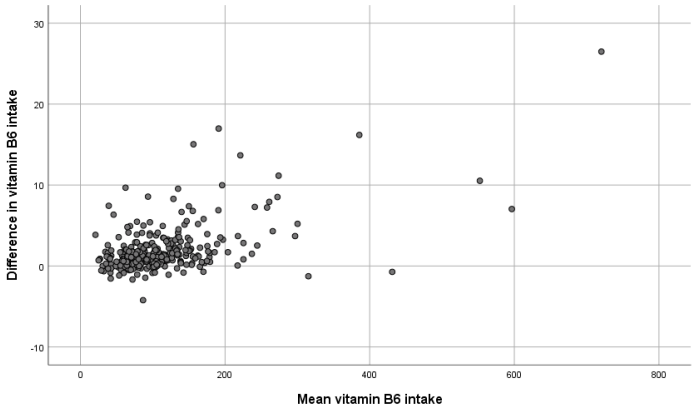
(N): Bland-Altman plot of niacin intake



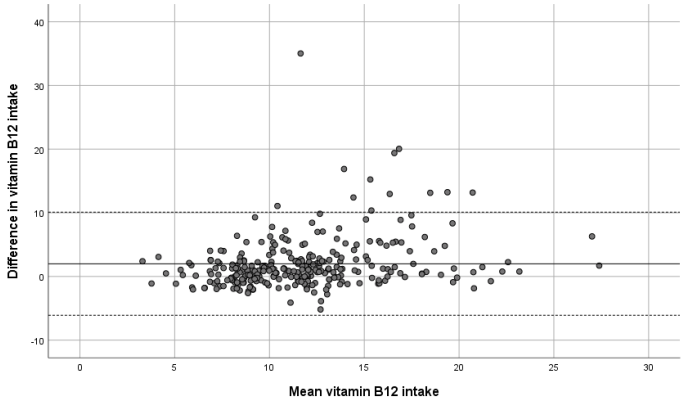
(Q): Bland-Altman plot of vitamin E intake



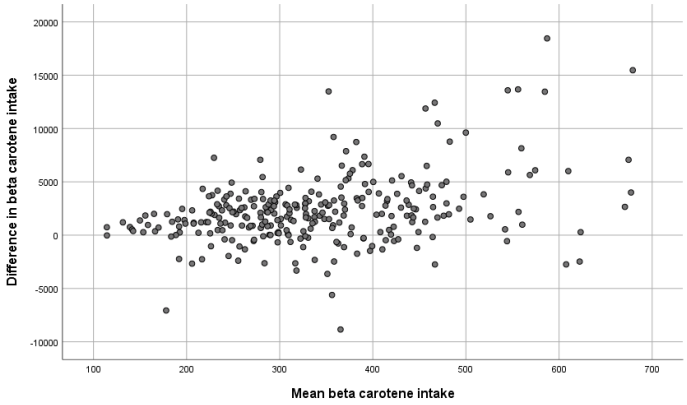
(O): Bland-Altman plot of niacin eq intake



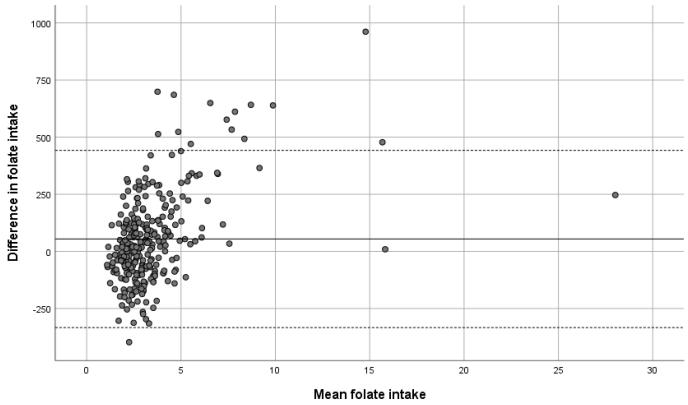
(R): Bland-Altman plot of vitamin B6 intake



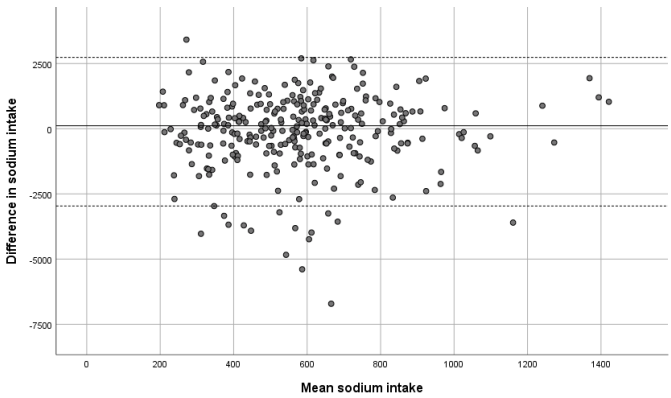
(S): Bland-Altman plot of B12 intake



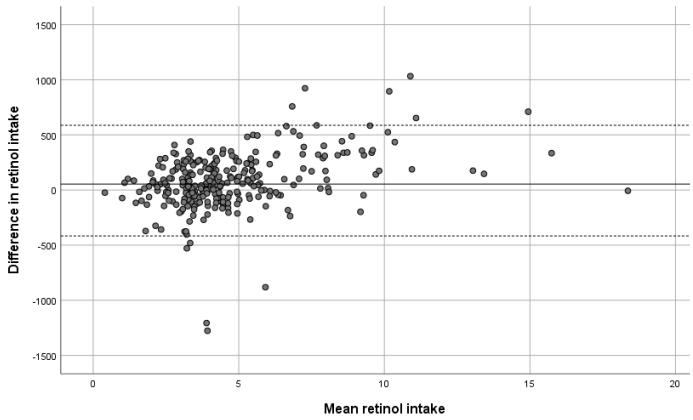
(V): Bland-Altman plot of beta-carotene intake



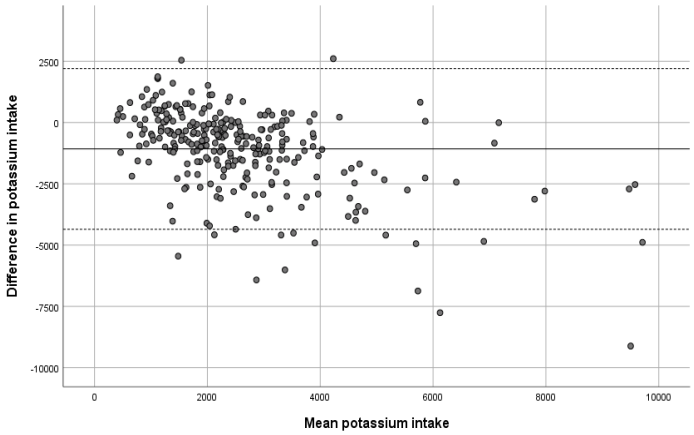
(T): Bland-Altman plot of folate intake



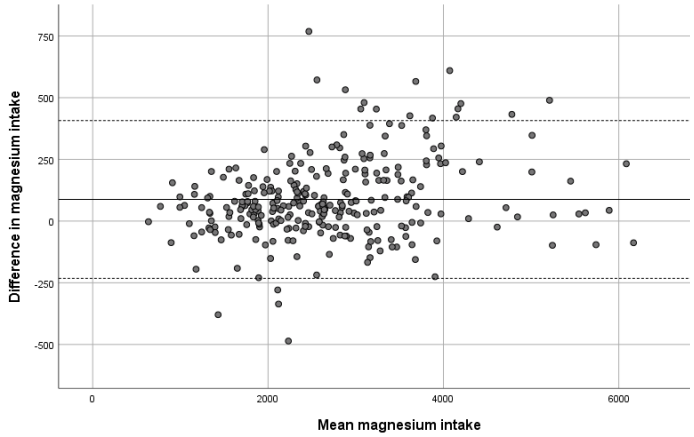
(W): Bland-Altman plot of sodium intake



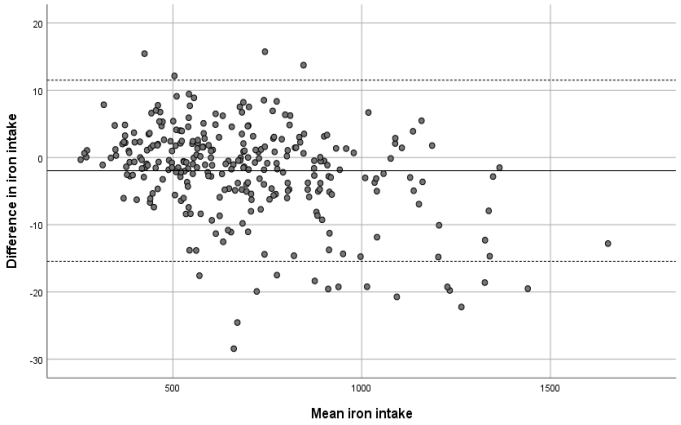
(U): Bland-Altman plot of retinol intake



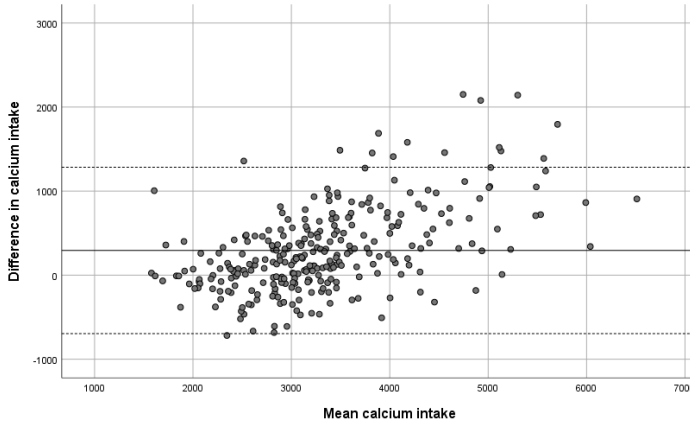
(X): Bland-Altman plot of potassium intake



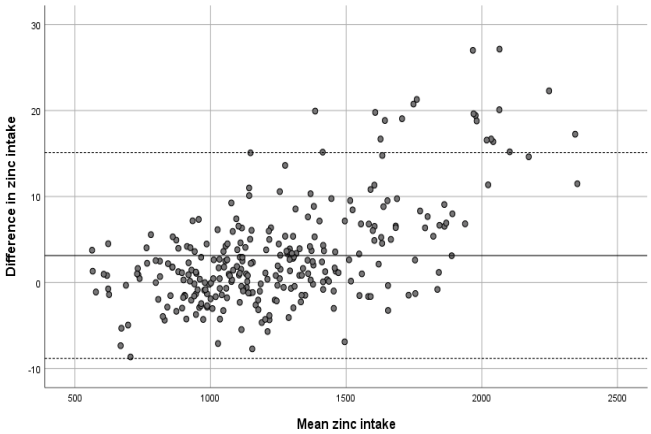
(Y): Bland-Altman plot of magnesium intake



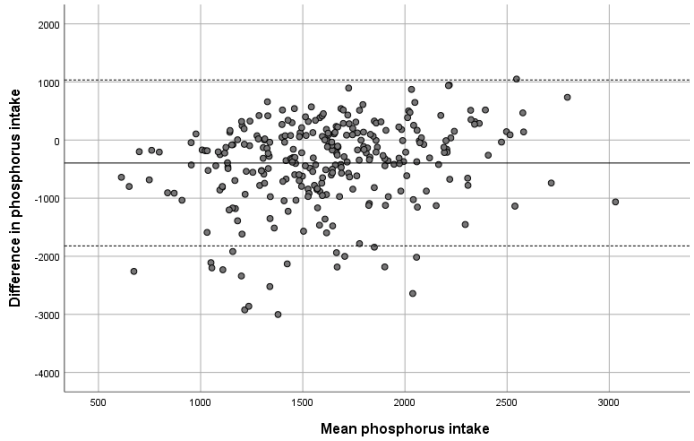
(AB): Bland-Altman plot of iron intake



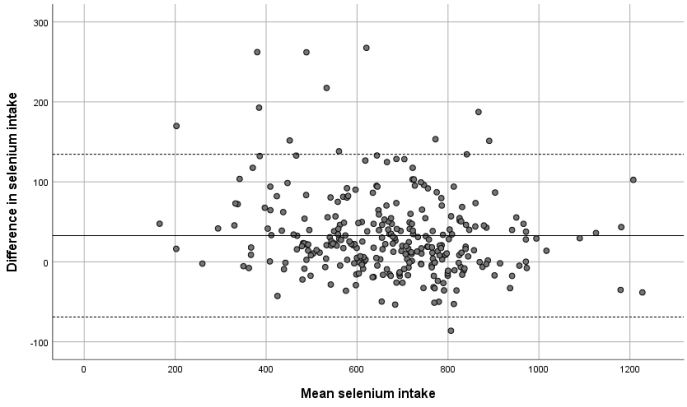
(Z): Bland-Altman plot of calcium intake



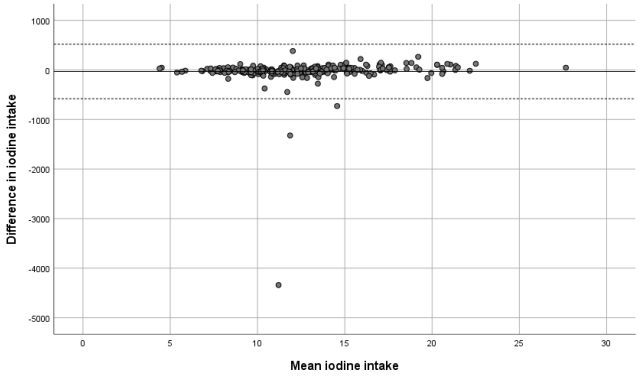
(AC): Bland-Altman plot of zinc intake



(AA): Bland-Altman plot of phosphorus intake

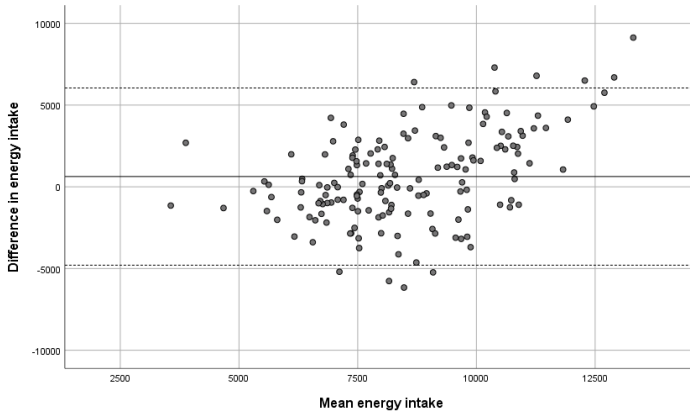


(AD): Bland-Altman plot of selenium intake

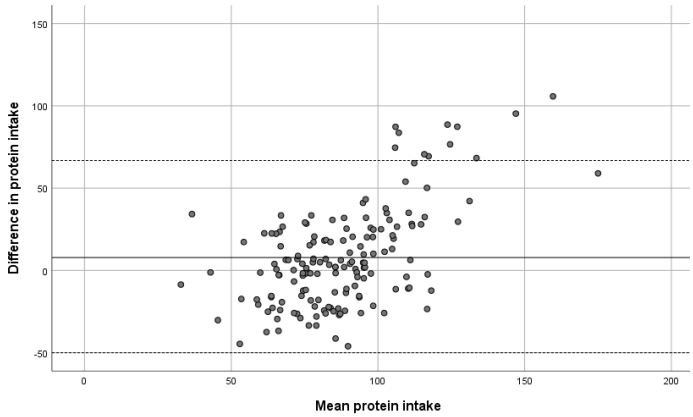


(

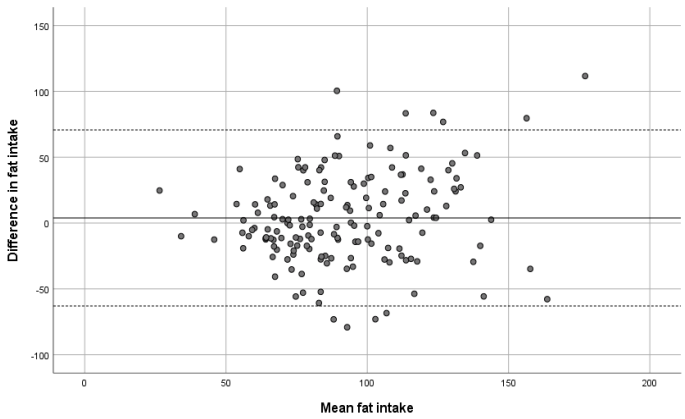
AE): Bland-Altman plot of iodine intake



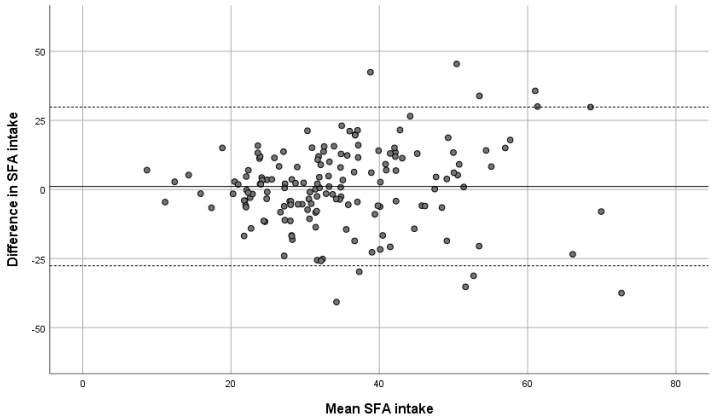
(A): Bland-Altman plot of energy intake



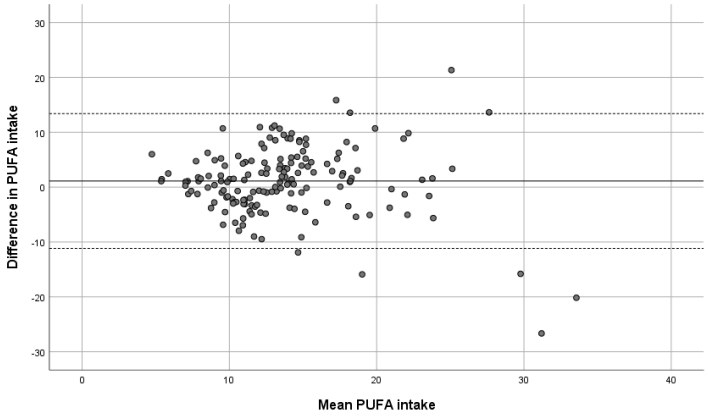
(B): Bland-Altman plot of protein intake



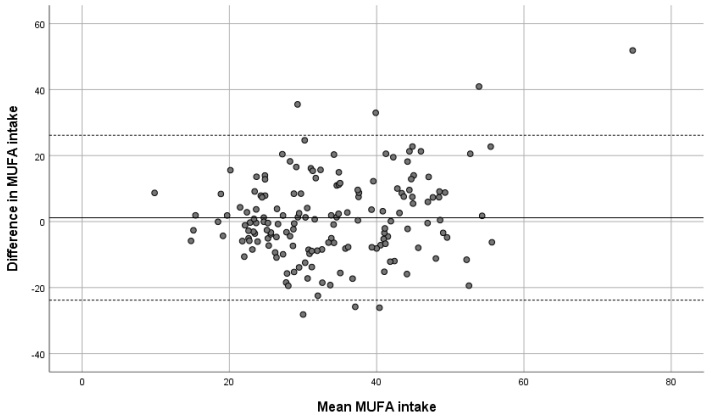
(C): Bland-Altman plot of fat intake



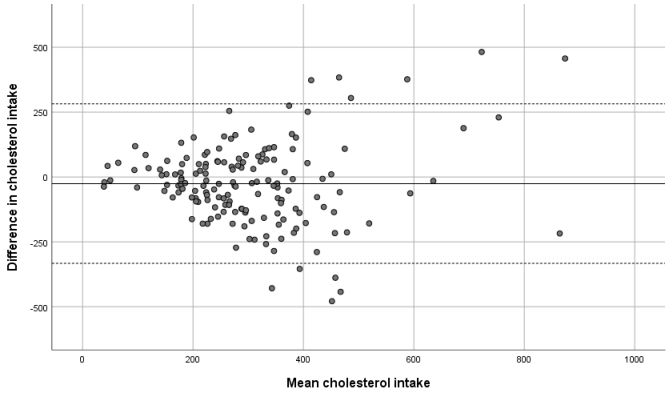
(D): Bland-Altman plot of saturated fat



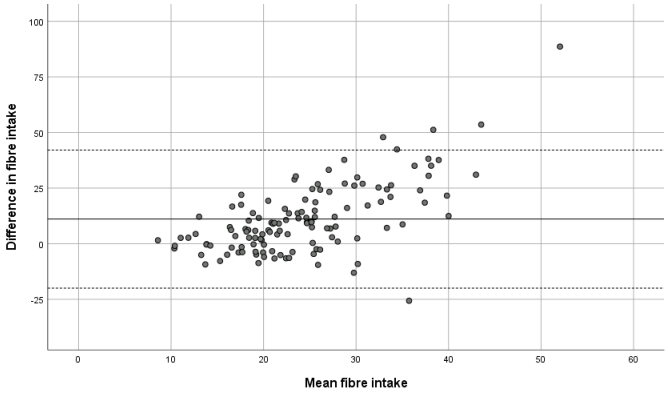
(E): Bland-Altman plot of polyunsaturated fat



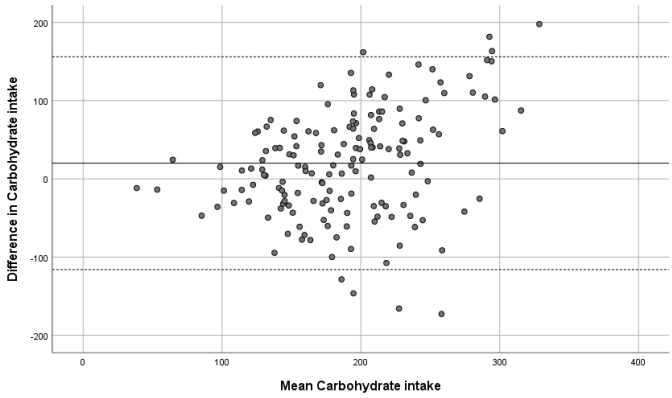
(F): Bland-Altman plot of monounsaturated fat



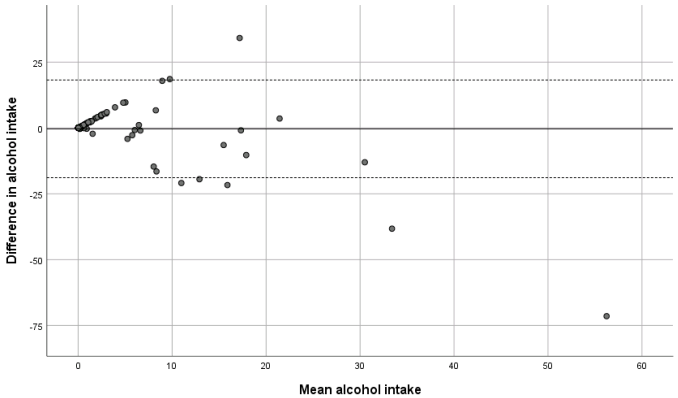
(G): Bland-Altman plot of cholesterol intake



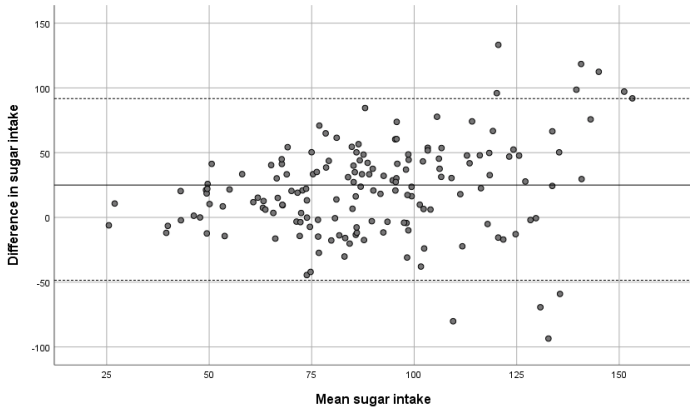
(J): Bland-Altman plot of cholesterol intake



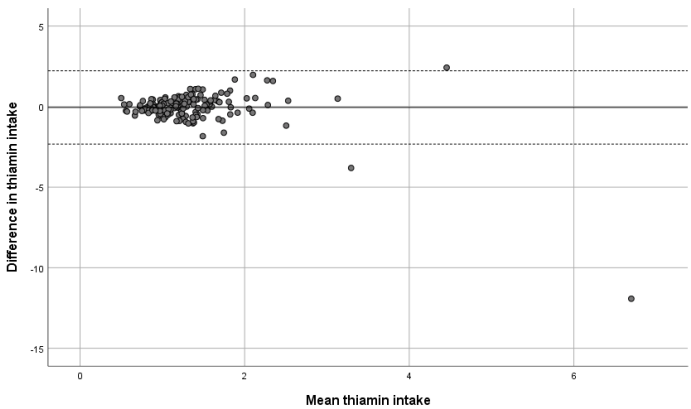
(H): Bland-Altman plot of carbohydrate intake



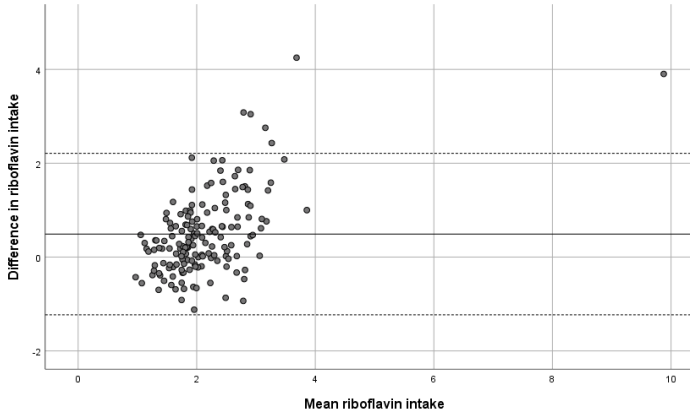
(K): Bland-Altman plot of alcohol intake



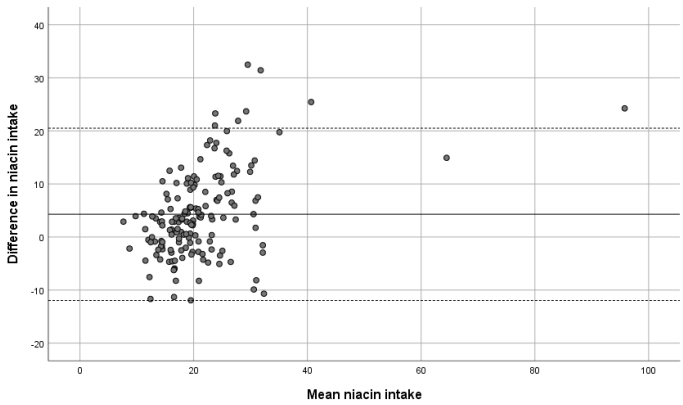
(I): Bland-Altman plot of sugar intake



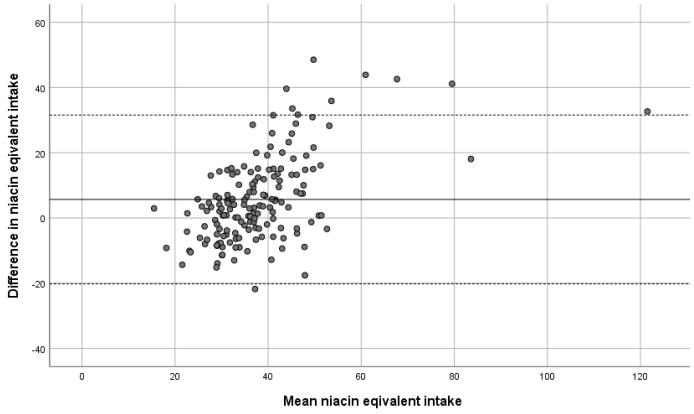
(L): Bland-Altman plot of thiamin intake



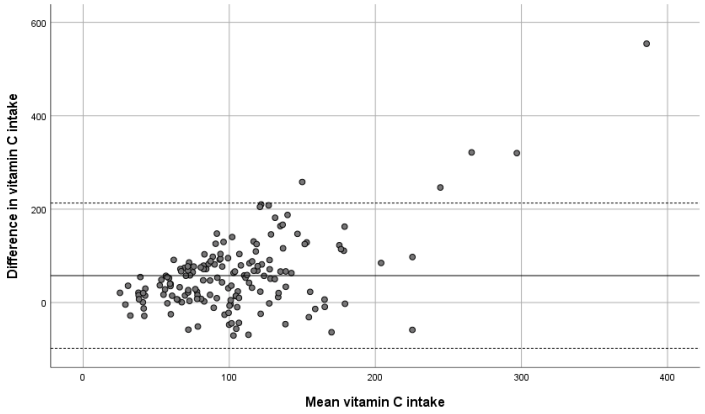
(M): Bland-Altman plot of riboflavin intake



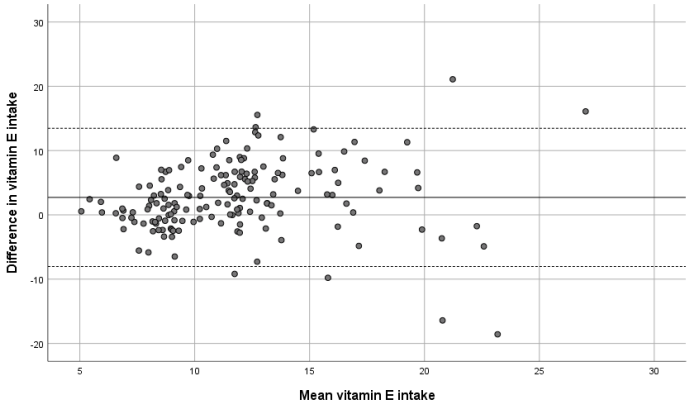
(N): Bland-Altman plot of niacin intake



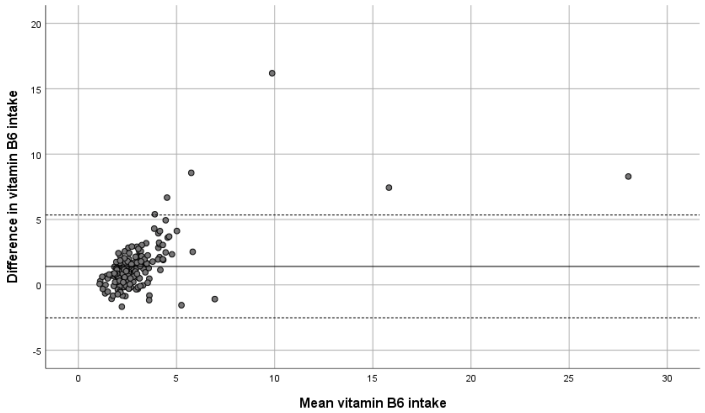
(O): Bland-Altman plot of niacin eq intake



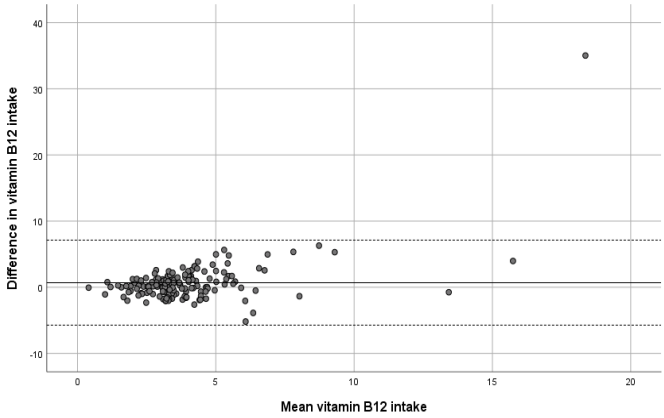
(P): Bland-Altman plot of vitamin C intake



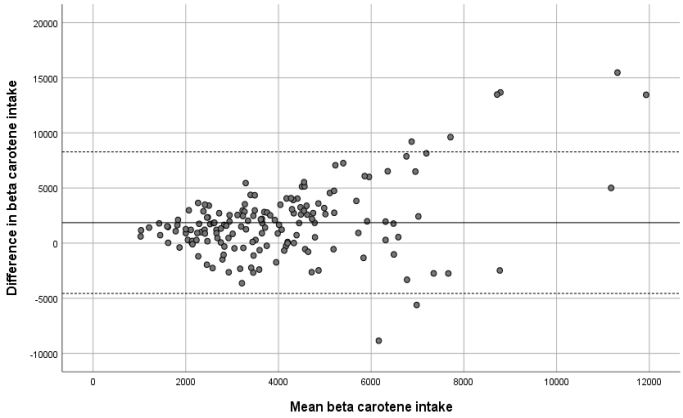
(Q): Bland-Altman plot of vitamin E intake



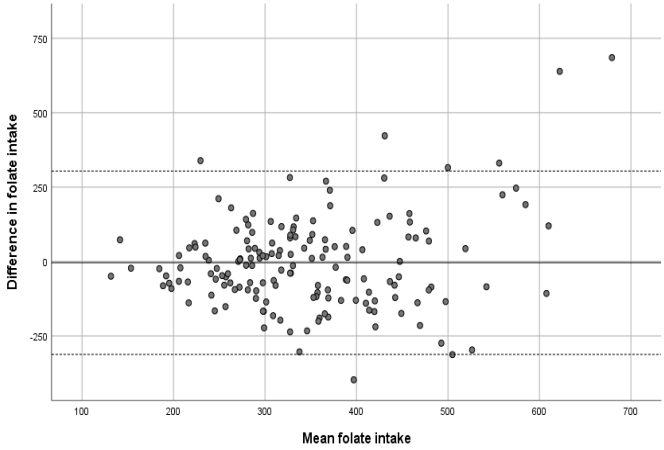
(R): Bland-Altman plot of vitamin B6 intake



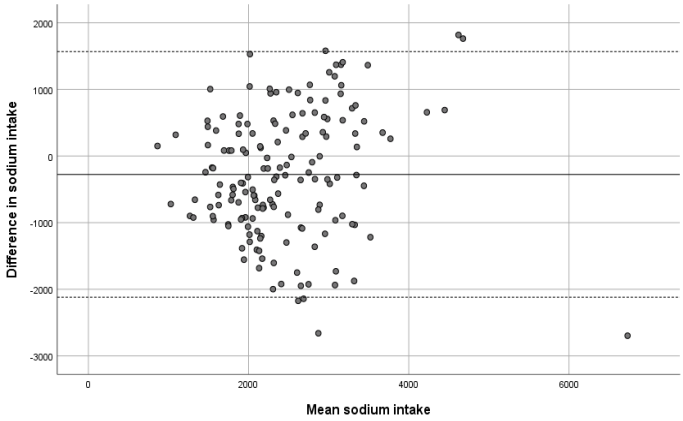
(S): Bland-Altman plot of vitamin B12 intake



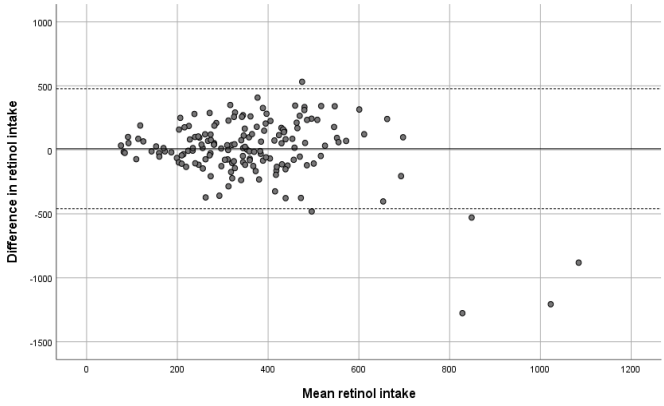
(V): Bland-Altman plot of beta carotene intake



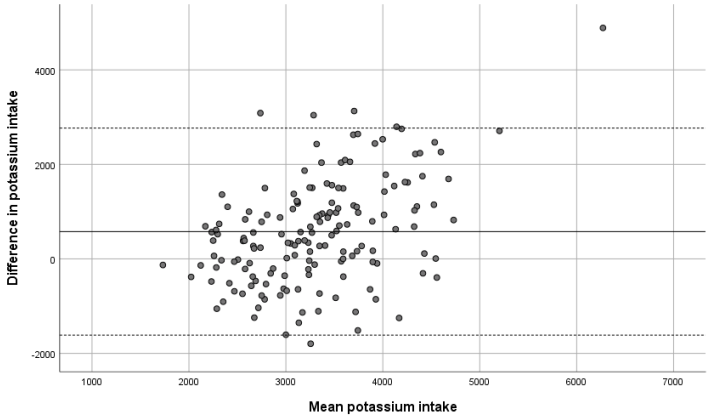
(T): Bland-Altman plot of folate intake



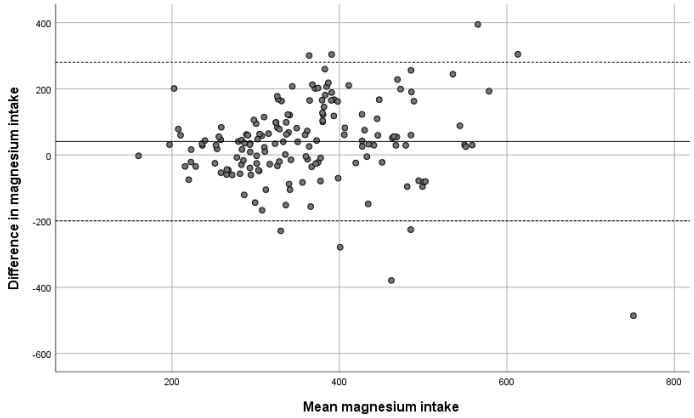
(W): Bland-Altman plot of sodium intake



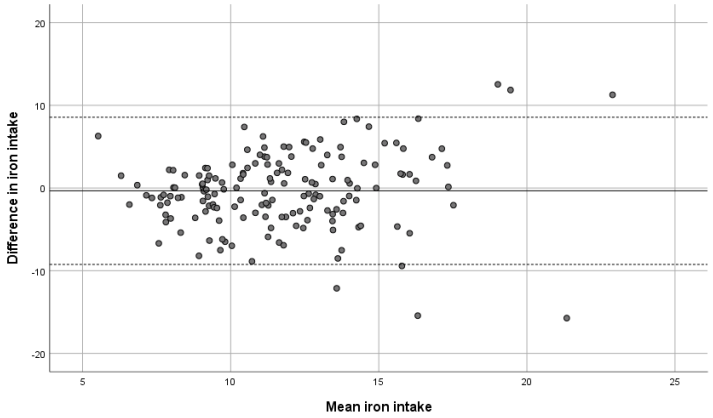
(U): Bland-Altman plot of retinol intake



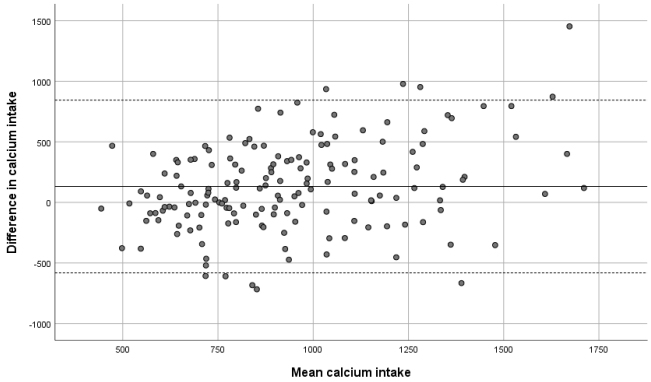
(X): Bland-Altman plot of potassium intake



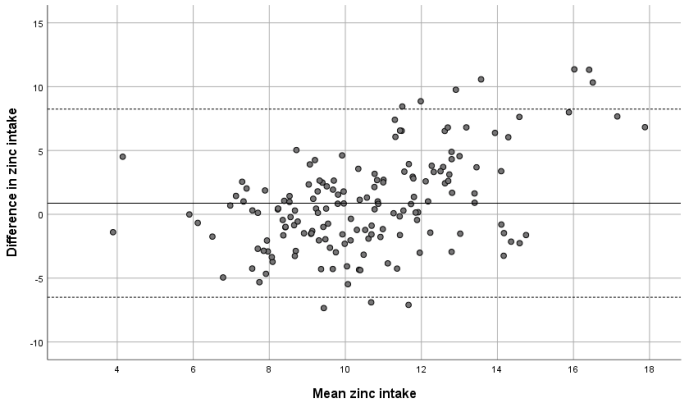
(Y): Bland-Altman plot of magnesium intake



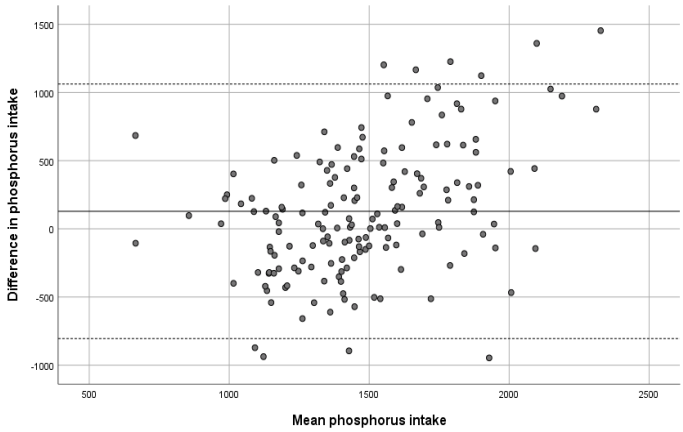
(AB): Bland-Altman plot of iron intake



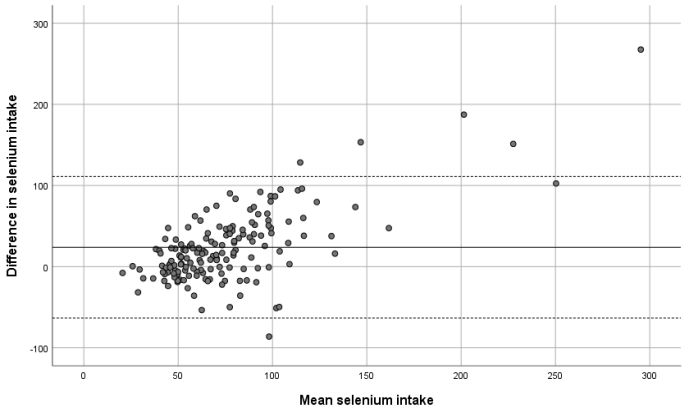
(Z): Bland-Altman plot of calcium intake



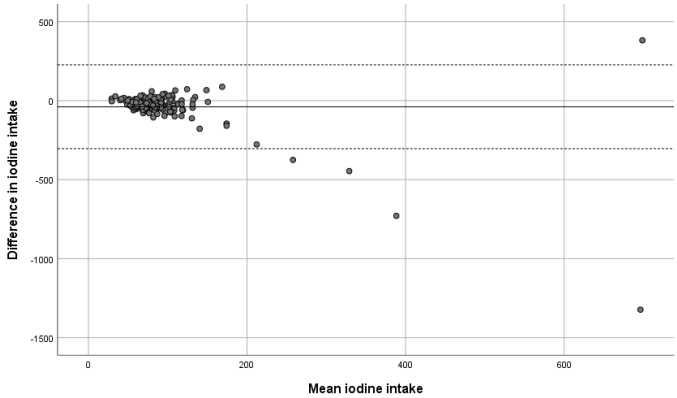
(AC): Bland-Altman plot of zinc intake



(AA): Bland-Altman plot of phosphorus

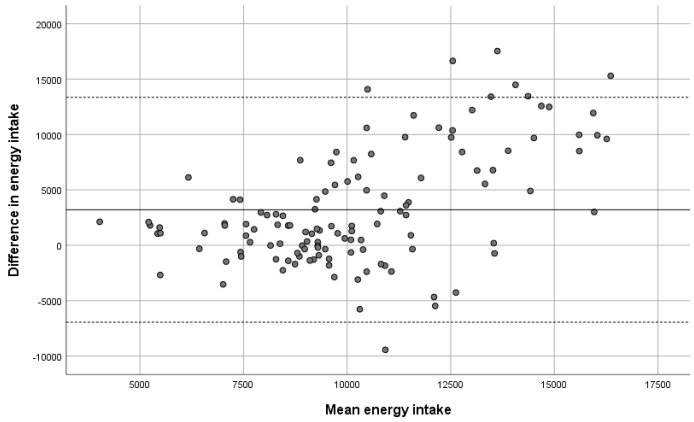


(AD): Bland-Altman plot of selenium intake

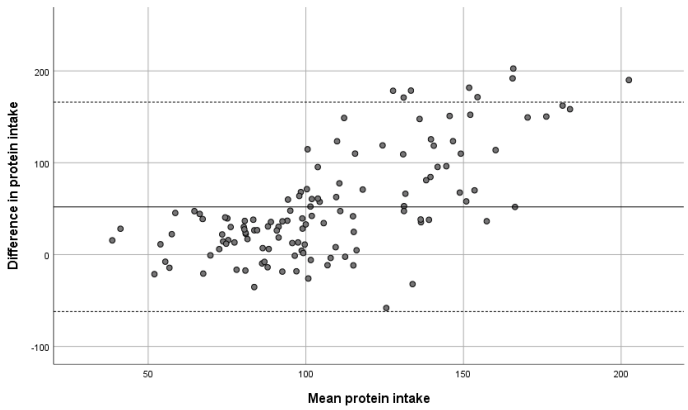


(AE): Bland-Altman plot of iodine intake

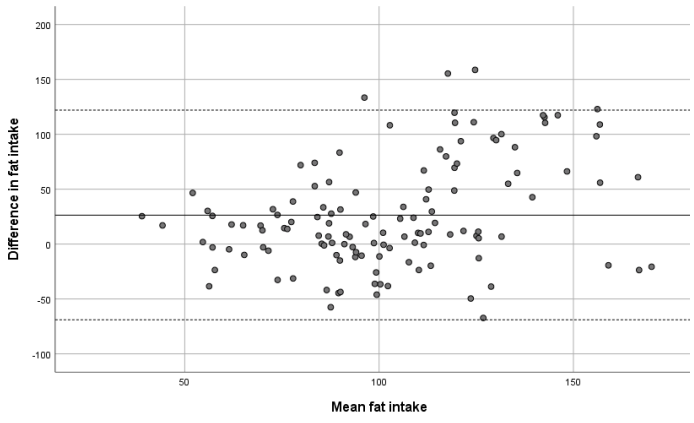
Pacific women



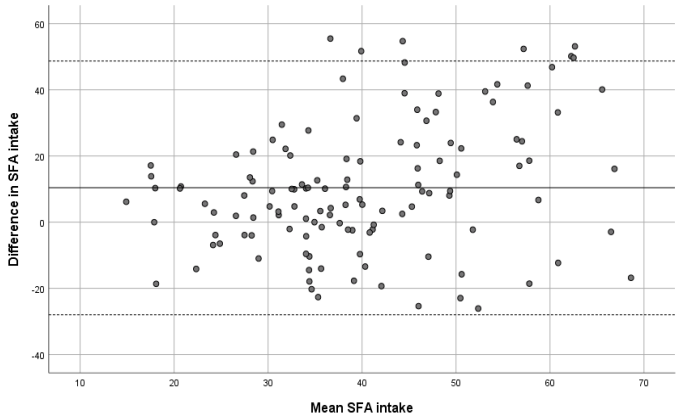
(A): Bland-Altman plot of energy intake



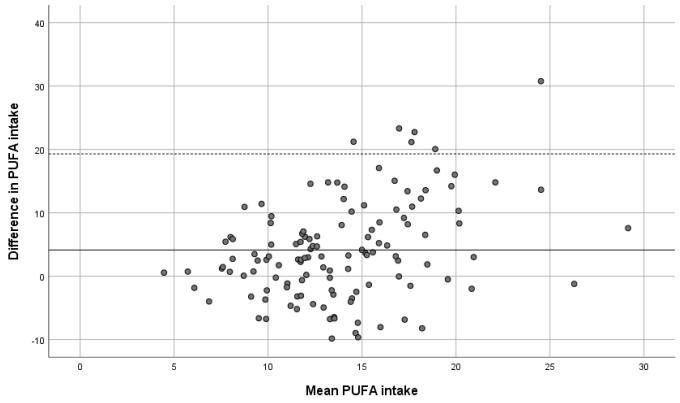
(B): Bland-Altman plot of protein intake



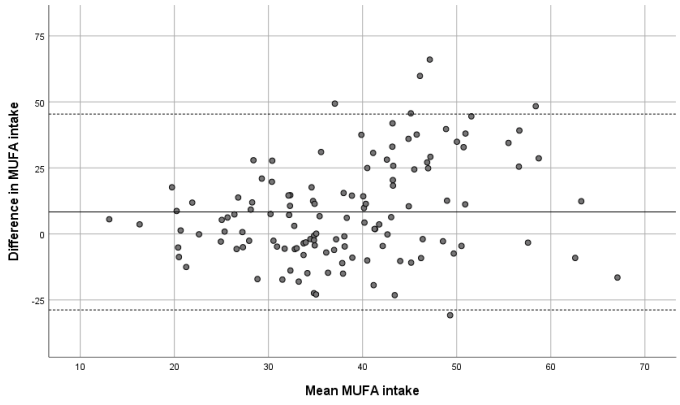
(C): Bland-Altman plot of fat intake



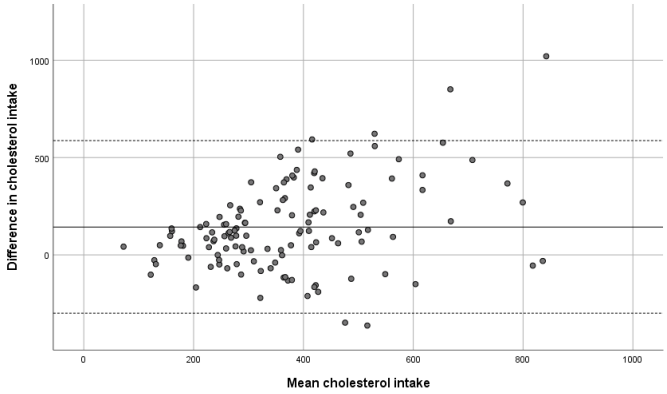
(D): Bland-Altman plot of saturated fat intake



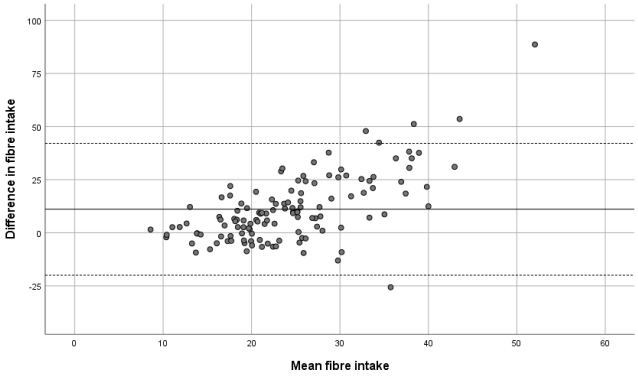
(E): Bland-Altman plot of polyunsaturated fat intake



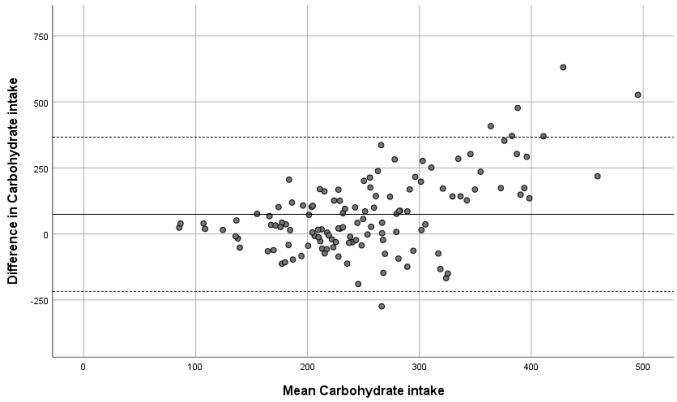
(F): Bland-Altman plot of monounsaturated fat intake



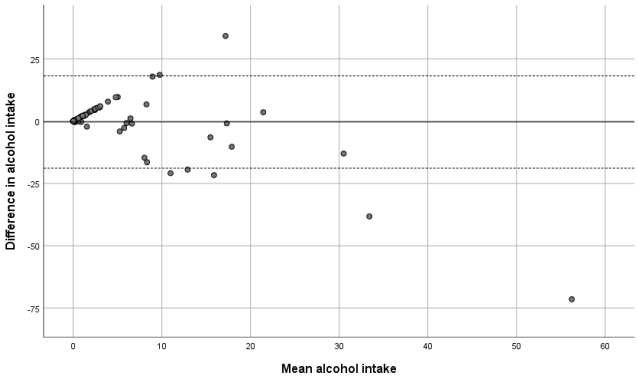
(G): Bland-Altman plot of cholesterol intake



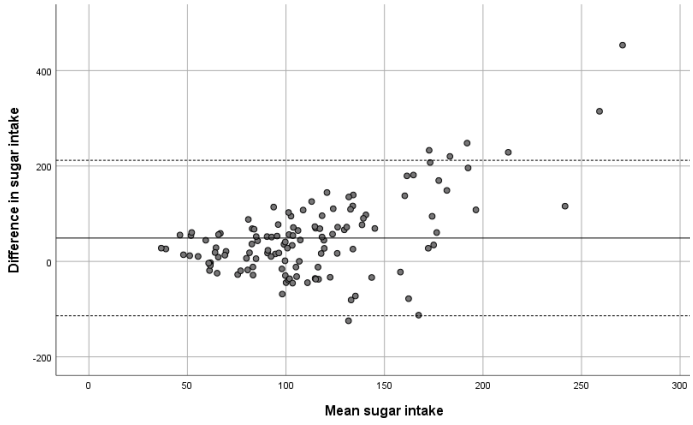
(J): Bland-Altman plot of fibre intake



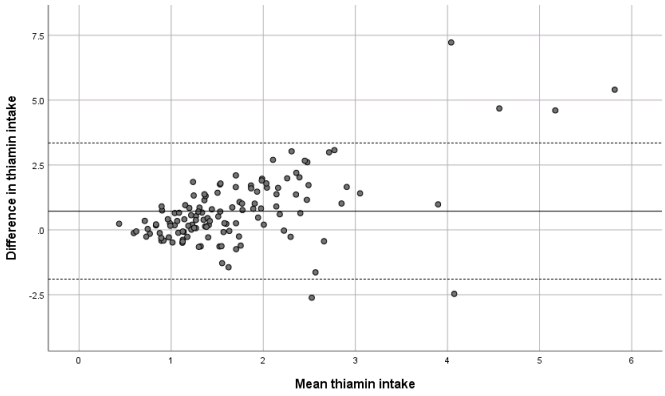
(H): Bland-Altman plot of carbohydrate intake



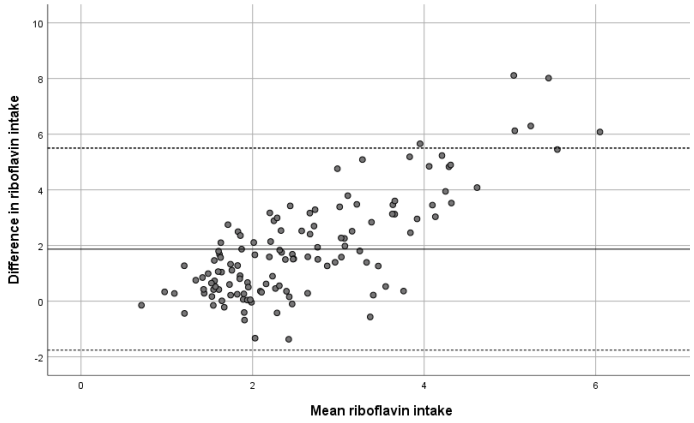
(K): Bland-Altman plot of alcohol intake



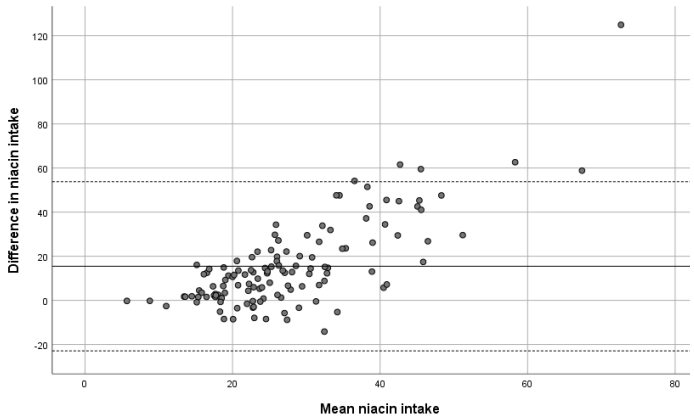
(I): Bland-Altman plot of sugar intake



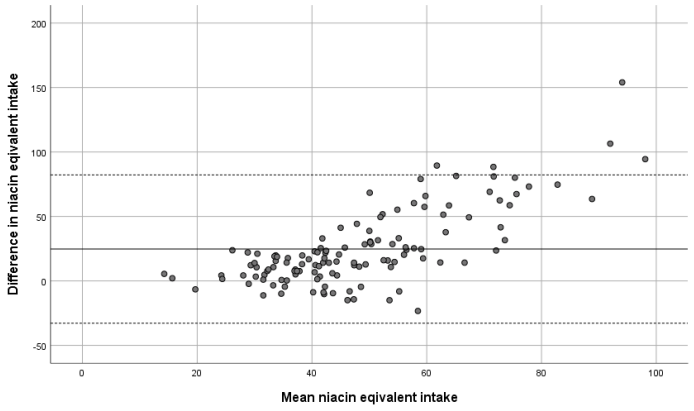
(L): Bland-Altman plot of thiamin intake



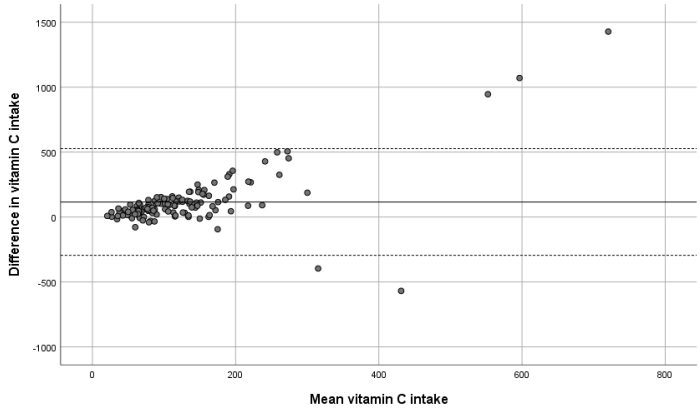
(M): Bland-Altman plot of riboflavin intake



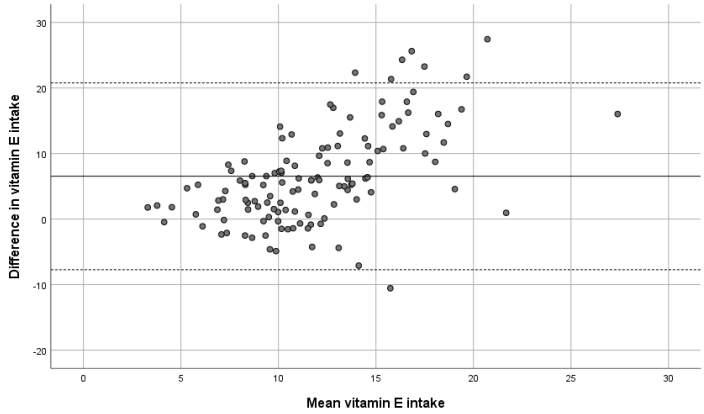
(N): Bland-Altman plot of niacin intake



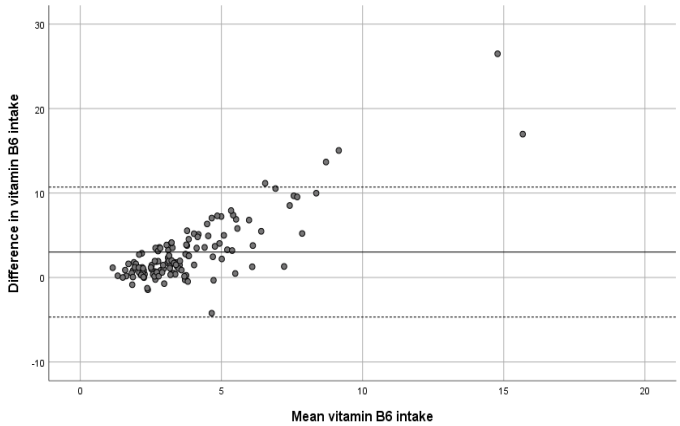
(O): Bland-Altman plot of niacin eq intake



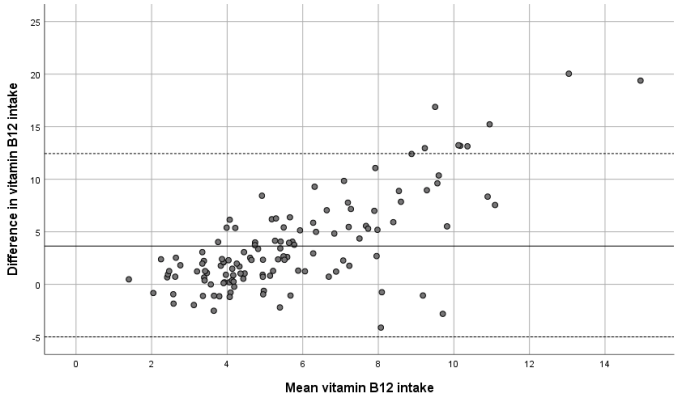
(P): Bland-Altman plot of vitamin C intake



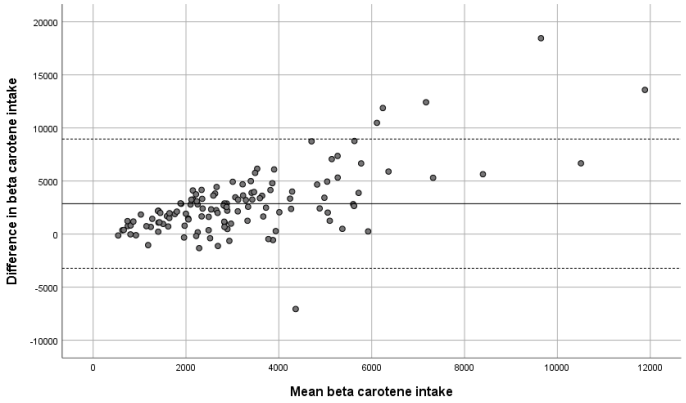
(Q): Bland-Altman plot of vitamin E intake



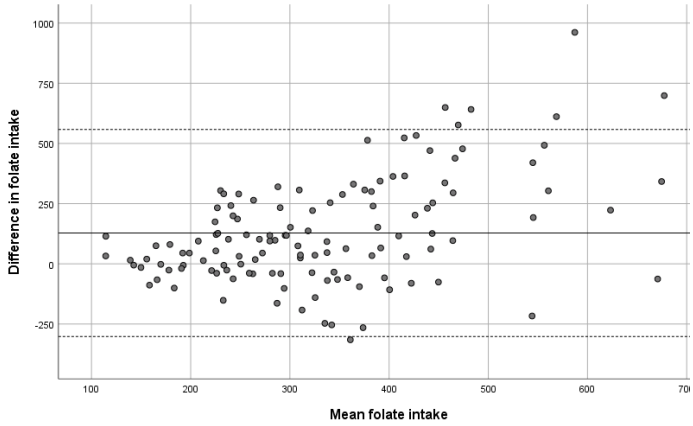
(R): Bland-Altman plot of vitamin B6 intake



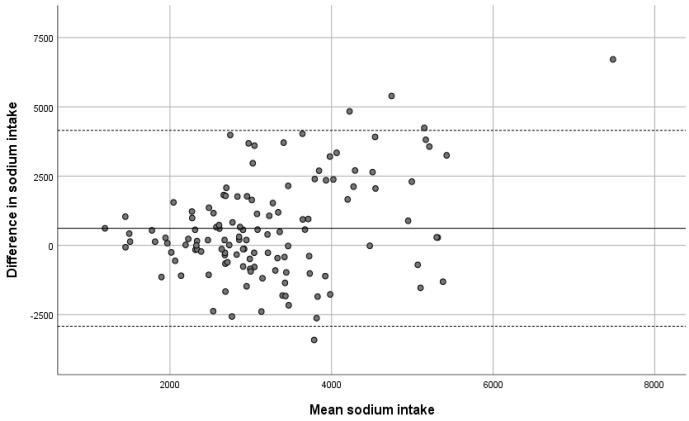
(S): Bland-Altman plot of vitamin B12 intake



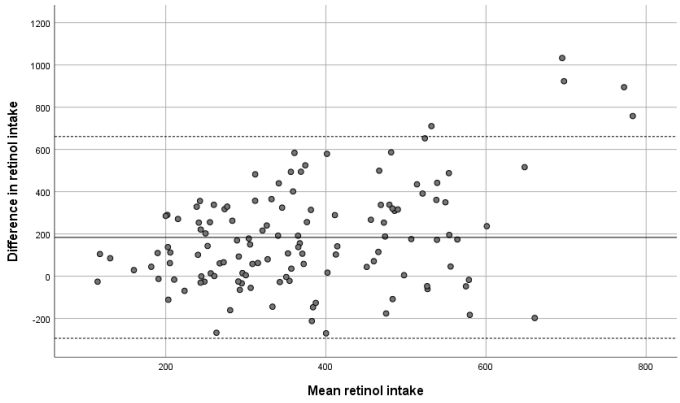
(V): Bland-Altman plot of Beta-carotene intake



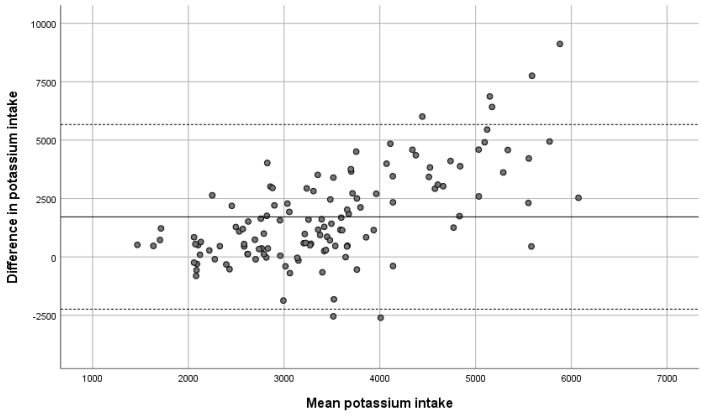
(T): Bland-Altman plot of folate intake



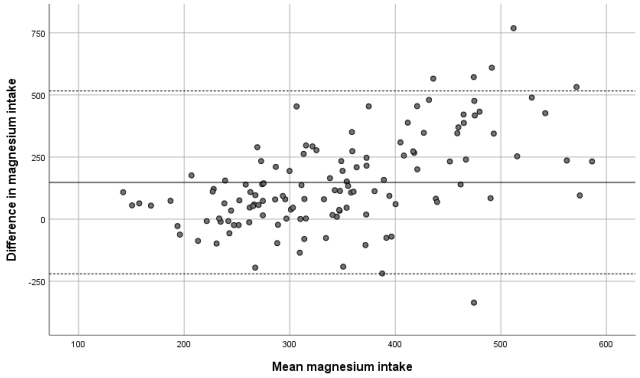
(W): Bland-Altman plot of sodium intake



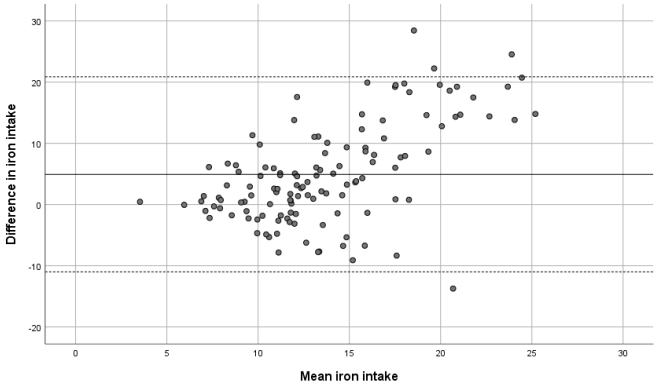
(U): Bland-Altman plot of retinol intake



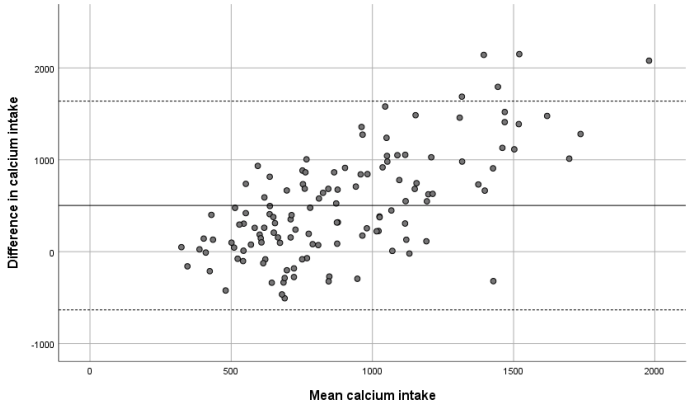
(X): Bland-Altman plot of potassium intake



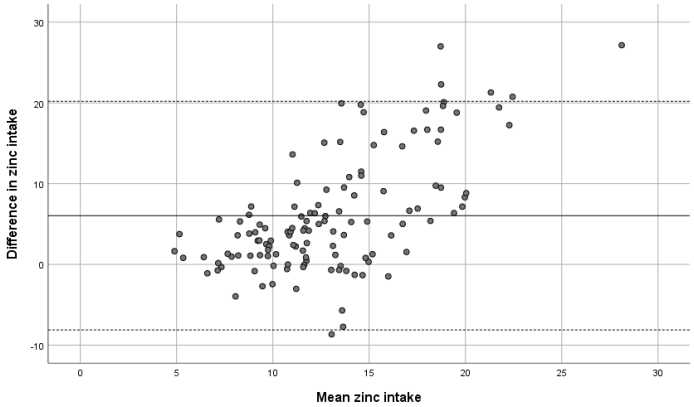
(Y): Bland-Altman plot of magnesium intake



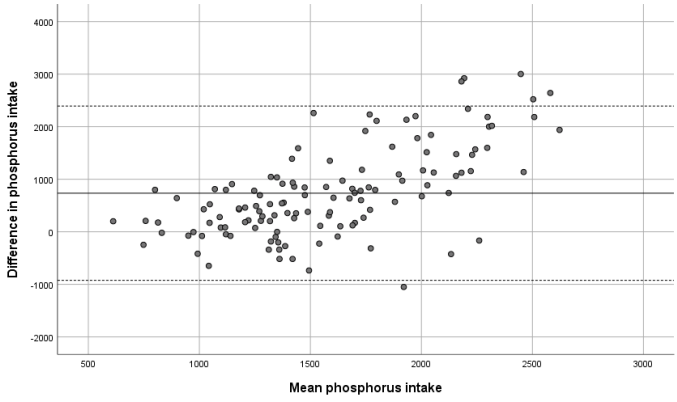
(AB): Bland-Altman plot of iron intake



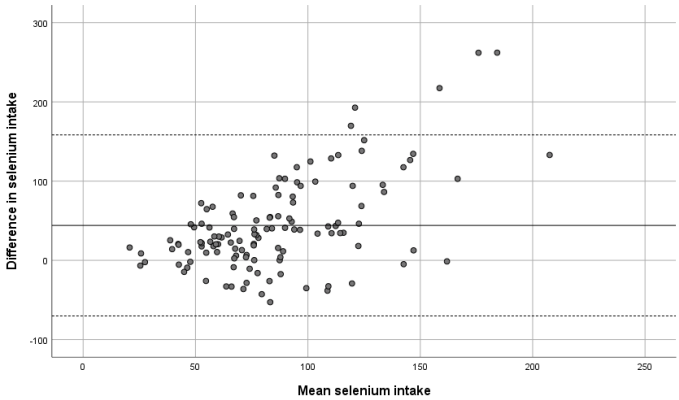
(Z): Bland-Altman plot of calcium intake



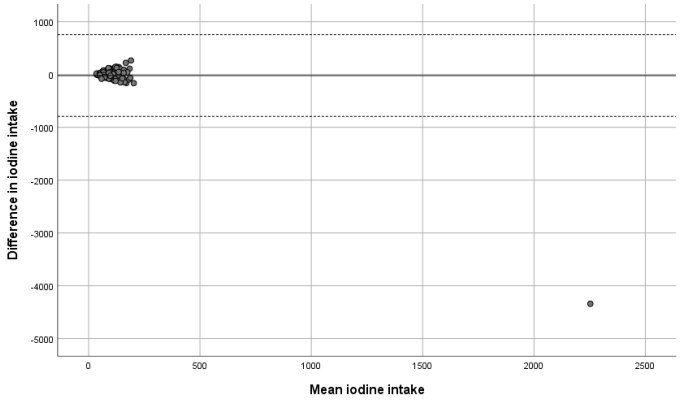
(AC): Bland-Altman plot of zinc intake



(AA): Bland-Altman plot of phosphorous intake



(AD): Bland-Altman plot of selenium intake



(AE): Bland-Altman plot of iodine intake

Supplementary Results continued

Table A1: Bland-Altman Spearman's Correlation Coefficient

	Total group (n=287)		**NZ European (n=161)**		**Pacific (n=126)**	
Nutrient	Correlation (*r*)	P-value*	Correlation (*r*)	P-value*	Correlation (*r*)	P-value*
Total energy (kJ)	0.45	<0.001	0.43	<0.001	0.45	<0.001
Protein (g)	0.57	0.00	0.46	<0.001	0.64	<0.001
Total fat (g)	0.26	0.00	0.17	0.3	0.31	0.001
SFA (g)	0.24	<0.001	0.16	0.04	0.27	0.002
PUFA (g)	0.21	<0.001	0.12	0.15	0.33	0.002
MUFA (g)	0.22	<0.001	0.16	0.09	0.34	0.002
Cholesterol (mg)	0.18	0.002	-0.11	0.18	0.32	<0.001
Carbohydrates (g)	0.38	<0.001	0.32	<0.001	0.44	<0.001
Sugars (g)	0.34	<0.001	0.28	<0.001	0.41	<0.001
Dietary fibre (g)	0.20	<0.001	0.31	<0.001	0.57	<0.001
Alcohol (g)	0.50	0.427	-0.12	0.12	0.22	0.02
Thiamin (mg)	-0.45	0.45	0.17	0.03	0.49	<0.001
Riboflavin (mg)	0.18	<0.001	0.47	<0.001	0.65	<0.001
Niacin (mg)	0.36	<0.001	0.42	<0.001	0.63	<0.001
Niacin equivalents (mg)	0.44	<0.001	0.50	<0.001	0.66	<0.001
Vitamin C (mg)	0.39	<0.001	0.32	<0.001	0.56	<0.001
Vitamin E (mg)	0.48	<0.001	0.27	<0.001	0.57	<0.001
Vitamin B6 (mg)	0.36	<0.001	0.53	<0.001	0.66	<0.001
Vitamin B12 (µg)	0.26	<0.001	0.26	0.001	0.62	<0.001
Folate (µg)	0.40	<0.001	0.03	0.69	0.40	<0.001
Retinol (µg)	0.36	<0.001	0.48	0.55	0.26	0.003
Beta carotene equivalents (µg)	0.30	<0.001	0.27	0.001	0.58	<0.001
Sodium (mg)	0.40	0.56	0.18	0.02	0.21	0.02
Potassium (mg)	-0.46	<0.001	0.40	<0.001	0.59	<0.001
Magnesium (mg)	0.23	<0.001	0.23	0.003	0.55	<0.001
Calcium (mg)	0.53	<0.001	0.29	<0.001	0.61	<0.001
Phosphorus (mg)	0.24	<0.001	0.40	<0.001	0.61	<0.001
Iron (mg)	-0.31	<0.001	0.17	0.03	0.53	<0.001
Zinc (mg)	0.48	<0.001	0.40	<0.001	0.57	<0.001
Selenium (µg)	-0.18	<0.001	0.52	<0.001	0.47	<0.001
Iodine (µg)	0.24	<0.001	-0.20	0.01	0.05	0.60

Appendix B: The New Zealand Women's Food Frequency Questionnaire

EXPLORE Food Frequency Questionnaire

1. Please read carefully before you begin:

Please make sure when filling out this questionnaire that you:

• Tell us what YOU usually eat (not someone else in your household!).
• Fill in the form YOURSELF.
• Are correct, but don't spend too much time on each food.
• Answer EVERY question; the asterisk symbol (*) at the beginning of each question means that you must answer before moving onto the next question.

This will help us to get the most accurate information about your usual food intake.

Please answer by ticking the box which best describes HOW OFTEN you ate or drank a particular food or drink in the LAST MONTH and HOW MUCH you would usually have.

For example:

1. EXAMPLE: How often do you usually have sugar? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Sugar - 1 tsp	○	○	○	○	○	○	○	○	○

If every day you have 2 cups of coffee with 1 tsp sugar, 4 cups of tea with 1 tsp sugar, one bowl of cereal with 1 tsp sugar and sugar on pancakes at dinner, you would choose four or more times per day = '4+ x / day'.

Adjust your portion size and frequency of intake to suit your eating habits.

2. EXAMPLE: How often do you usually eat bread? (Please do not fill out)

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Bread - 1 slice	○	○	○	○	○	○	○	○	○

If every day you have two slices of toast for breakfast, and you have a sandwich for lunch three times per week, you would choose two - three times per day = '2-3x / day'.

Adjust your portion size and frequency of intake to suit your eating habits.

EXPLORE Food Frequency Questionnaire

2. EXPLORE Study Food Frequency Questionnaire

* 1. Please enter your study ID (if you are unsure or don't know please ask the researcher)

EXPLORE Food Frequency Questionnaire

3. Eating Pattern

* 1. How would you describe your eating pattern? (Please choose one only)

- ◯ Eat a variety of all foods, including animal products
- ◯ Eat eggs, dairy products, fish and chicken but avoid other meats
- ◯ Eat eggs, dairy products and fish, but avoid chicken and other red meats
- ◯ Eat eggs and dairy products, but avoid all meats, chicken and fish
- ◯ Eat eggs, but avoid dairy products, all meats and fish
- ◯ Eat dairy products, but avoid eggs, all meats and fish
- ◯ Eat no animal products
- ◯ None of the above

Other (please state)

EXPLORE Food Frequency Questionnaire

4. Dairy

* 1. Do you use milk? (e.g. fresh, UHT, powdered)

- ◯ Yes
- ◯ No

* 2. What type(s) of milk do you have most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- [ ] Not applicable
- [ ] Full cream milk (purple top)
- [ ] Standard milk (blue top)
- [ ] Skim milk (light blue top)
- [ ] Trim milk (green top)
- [ ] Super trim milk (light green top)
- [ ] Calcium enriched milk (yellow top) e.g. Xtra, Calci-Trim
- [ ] Calcium and vitamin enriched milk e.g. Mega, Anlene
- [ ] Calcium and protein enriched milk e.g. Sun Latte
- [ ] Standard soy milk (blue)
- [ ] Light soy milk (light blue)
- [ ] Calcium enriched soy milk (purple) e.g. Calci-Forte, Calci-Plus
- [ ] Calcium, vitamin and omega 3 enriched soy milk e.g. Essential
- [ ] Calcium and high fibre enriched soy milk e.g. Calci-Plus High Fibre
- [ ] Rice milk

Other (please state)

* 3. Choose the one milk you have the most

- [ ] Not applicable
- [ ] Full cream milk (purple top)
- [ ] Standard milk (blue top)
- [ ] Skim milk (light blue)
- [ ] Trim milk (green top)
- [ ] Super trim milk (light green top)
- [ ] Calcium enriched milk (yellow top) e.g. Xtra, Calci-Trim
- [ ] Calcium and vitamin enriched milk e.g. Mega, Anlene
- [ ] Calcium and protein enriched milk e.g. Sun Latte
- [ ] Standard soy milk (blue)
- [ ] Light soy milk (light blue)
- [ ] Calcium enriched soy milk (purple) e.g. Calci-Forte, Calci-Plus
- [ ] Calcium, vitamin and omega 3 enriched soy milk e.g. Essential
- [ ] Calcium and high fibre enriched soy milk e.g. Calci-Plus High Fibre
- [ ] Rice milk

Other (please state)

* 4. On average, how many servings of milk do you have per day? (Please choose one only)
(A 'serving' = 250 mL or 1 cup/glass)
e.g. 5 cups of coffee/tea using 50 mL of milk + ½ cup of milk on cereal = 1 ½ servings per day

- ○ Not applicable
- ○ Less than 1 serving
- ○ 1-2 servings
- ○ 3-4 servings
- ○ 5 or more servings

* 5. How often do you usually have milk?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Flavoured milk (milkshake, iced coffee, Primo, Nesquik) - 250 mL/ 1 cup	○	○	○	○	○	○	○	○	○
Milk as a drink - 250 mL / 1 cup	○	○	○	○	○	○	○	○	○
Milk on breakfast cereals or porridge - 125 mL/ 1/2 cup	○	○	○	○	○	○	○	○	○
Milk added to water-based hot drinks (coffee, tea) - 50 mL / 1/5 cup	○	○	○	○	○	○	○	○	○
Milk-based hot drinks (Latte, Milo) - 250 mL / 1 cup	○	○	○	○	○	○	○	○	○

* 6. How often do you usually eat cheese?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day	4+ x / day
Cheddar (tasty, mild, colby) - 2 heaped Tbsp / matchbox cube	○	○	○	○	○	○	○	○	○	○
Edam, Gouda, Swiss - 2 heaped Tbsp / matchbox cube	○	○	○	○	○	○	○	○	○	○
Feta, Mozarella, Camembert - 1 heaped Tbsp / 1 med wedge	○	○	○	○	○	○	○	○	○	○
Brie, blue and other specialty cheese - 1 heaped Tbsp / 1 med wedge	○	○	○	○	○	○	○	○	○	○
Processed cheese slices - 1 slice	○	○	○	○	○	○	○	○	○	○
Cream cheese - 2 heaped Tbsp	○	○	○	○	○	○	○	○	○	○
Cottage or ricotta cheese - 2 heaped Tbsp	○	○	○	○	○	○	○	○	○	○

* 7. How often do you usually eat these dairy based foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Ice cream - 2 scoops	○	○	○	○	○	○	○	○	○
Custard or dairy food - 1 pottle / ½ cup	○	○	○	○	○	○	○	○	○
Yoghurt, plain or flavour - 1 pottle / ½ cup	○	○	○	○	○	○	○	○	○
Milk puddings (semolina, instant) - ½ cup	○	○	○	○	○	○	○	○	○
Fermented or evaporated milk (buttermilk) - ½ cup	○	○	○	○	○	○	○	○	○

EXPLORE Food Frequency Questionnaire

5. Bread

* 1. Do you eat bread?

- ○ No
- ○ Yes

* 2. What type(s) of bread, rolls or toast do you eat most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ White
- ☐ White – high fibre
- ☐ Wholemeal or wheat meal
- ☐ Wholegrain

Other (please state)

* 3. What type of bread slice do you usually have? (Please choose one only)

- ○ Not applicable
- ○ Sandwich slice
- ○ Toast slice
- ○ Mixture of both sandwich and toast slices

* 4. On average, how many servings of bread do eat per day? (Please choose one only)
(A 'serving' = 1 slice of bread or 1 small roll)

- ○ Not applicable
- ○ Less than 1 serving
- ○ 1–2 servings
- ○ 3–4 servings
- ○ 5–6 servings
- ○ 7 or more servings

* 5. How often do you usually eat these bread based foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Plain white bread - 1 slice	○	○	○	○	○	○	○	○	○
High fibre white bread - 1 slice	○	○	○	○	○	○	○	○	○
Wholemeal or wheat meal - 1 slice	○	○	○	○	○	○	○	○	○
Wholegrain bread - 1 slice	○	○	○	○	○	○	○	○	○
Fruit bread or fruit bun - 1 slice	○	○	○	○	○	○	○	○	○
Wrap - 1 medium	○	○	○	○	○	○	○	○	○
Focaccia, bagel, pita, panini or other speciality breads - 1 medium	○	○	○	○	○	○	○	○	○
Paraoa Parai (fry bread) - 1 slice	○	○	○	○	○	○	○	○	○
Rewena bread - 1 slice	○	○	○	○	○	○	○	○	○
Doughboys or Maori bread - 1 slice	○	○	○	○	○	○	○	○	○

* 6. How often do you usually eat these other bread based foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Crumpet or muffin split - 1 crumpet / 1 whole muffin split	○	○	○	○	○	○	○	○	○
Scone - 1 medium	○	○	○	○	○	○	○	○	○
Bran muffin or savoury muffin - 1 medium	○	○	○	○	○	○	○	○	○
Croissant - 1 medium	○	○	○	○	○	○	○	○	○
Waffle, pancakes or pikelets - 1 medium / 2 small	○	○	○	○	○	○	○	○	○
Iced buns - 1 medium	○	○	○	○	○	○	○	○	○
Crackers (cream crackers, cruskits, corn / rice crackers, vitawheat) - 2 medium	○	○	○	○	○	○	○	○	○

* 7. Do you have butter, margarine or spreads on bread or crackers?

- ○ No
- ○ Yes

* 8. What type(s) do you have most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- [ ] Not applicable
- [ ] Butter (all varieties)
- [ ] Monounsaturated fat margarine e.g. Olive, Rice Bran, Canola Oil Spreads
- [ ] Polyunsaturated fat margarine e.g. Sunflower Oil Spreads
- [ ] Light monounsaturated fat margarine e.g. Olivio Spread Light
- [ ] Light polyunsaturated fat margarine e.g. Flora Spread Light
- [ ] Plant sterol enriched margarine e.g. Pro Active, Logical Spreads
- [ ] Light plant sterol enriched margarine e.g. Pro Active Spread Light
- [ ] Butter and margarine blend e.g. Country Soft, Butter Lea

Other (please state)

* 9. Choose the one you have the most

- [ ] Not applicable
- [ ] Butter (all varieties)
- [ ] Monounsaturated fat margarine e.g. Olive, Rice Bran, Canola Oil Spreads
- [ ] Polyunsaturated fat margarine e.g. Sunflower Oil Spreads
- [ ] Light monounsaturated fat margarine e.g. Olivio Spread Light
- [ ] Light polyunsaturated fat margarine e.g. Flora Spread Light
- [ ] Plant sterol enriched margarine e.g. Pro Active, Logical Spreads
- [ ] Light plant sterol enriched margarine e.g. Pro Active Spread Light
- [ ] Butter and margarine blend e.g. Country Soft, Butter Lea
- [ ] Other (please state)

* 10. On average, how many servings of butter, margarine or spreads do you have per day? (Please choose one only)
(A 'serving' = 1 level teaspoon or 5 mL)
e.g. 1 sandwich with butter thinly spread on two pieces of bread = 2 servings

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1–2 servings
- ◯ 3–4 servings
- ◯ 5–6 servings
- ◯ 7 or more servings

EXPLORE Food Frequency Questionnaire

6. Breakfast Cereals and Porridge

* 1. Do you usually eat breakfast cereal and/or porridge?

- ◯ No
- ◯ Yes

* 2. What breakfast cereal(s) do you eat most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ Weetbix
- ☐ Refined cereals e.g. Cornflakes or Rice Bubbles
- ☐ Bran based cereals including fruity varieties e.g. Special K, Muesli, All Bran
- ☐ Sweetened e.g. Nutrigrain, Cocoa Pops
- ☐ Porridge

Other (please state)

* 3. On average, how many servings of breakfast cereal or porridge do you have per week? (Please choose one only)
(A 'serving' = ½ cup porridge, muesli, cornflakes or 2 weetbix)
e.g. ½ cup of porridge 3 times per week + 2 weetbix 4 times a week = 7 servings per week

- ◯ Not applicable
- ◯ Less than 4 servings
- ◯ 4–6 servings
- ◯ 7–9 servings
- ◯ 10–12 servings
- ◯ 13–15 servings
- ◯ 16 or more servings

* 4. How often do you usually eat porridge or these cereal foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Porridge, rolled oats, oat bran, oat meal - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Muesli (all varieties) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Weetbix (all varieties) - 2 weetbix	◯	◯	◯	◯	◯	◯	◯	◯	◯
Cornflakes or rice bubbles - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bran cereals (All Bran, Bran Flakes) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bran based cereals (Sultana Bran, Sultana Bran Extra) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Light and fruity cereals (Special K, Light and Tasty) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chocolate based cereals (Milo cereal, Coco Pops) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sweetened cereals (Nutrigrain, Fruit Loops, Honey Puffs, Frosties) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Breakfast drinks (Up and Go) - Small carton / 250 mL	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

7. Starchy Foods

* 1. Do you eat any type of starchy foods such as rice, pasta, noodles and couscous?

- ◯ No
- ◯ Yes

* 2. On average, how many servings of starchy foods such as rice, pasta, noodles and couscous do you eat per week? (Please choose one only)
(A 'serving' = 1 cup cooked rice / pasta)
e.g. 1 cup of rice + ½ cup of pasta included in a lasagne pasta dish + 1 cup of spaghetti = 2.5 servings

- ◯ Not applicable
- ◯ Less than 4 servings
- ◯ 4–6 servings
- ◯ 7–9 servings
- ◯ 10–12 servings
- ◯ 13–15 servings
- ◯ 16 or more servings

* 3. How often do you usually eat these starchy foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Rice, white - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Rice, brown or wild - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pasta, white or wholegrain (spaghetti, vermicelli) - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned spaghetti (Watties) - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Instant noodles (2 minute noodles) - 1 packet	◯	◯	◯	◯	◯	◯	◯	◯	◯
Egg and rice noodles (hokkien noodles, udon) - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Other grain (quinoa, couscous, bulgar wheat) - 1 cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

8. Meat

* 1. Do you eat beef, mutton, hogget, lamb, or pork

- ◯ No
- ◯ Yes

* 2. Do you trim any excess fat (fat you can see) off these meats? (Please choose one only)

- ◯ Not applicable
- ◯ Always
- ◯ Often
- ◯ Occasionally
- ◯ Never cut the fat off meat

* 3. On average, how many servings of meat e.g. beef, mutton, hogget, lamb or pork do you eat per week? (Please choose one only)
(A 'serving' = palm size or ½ a cup of meat without bone)
e.g. ½ cup of savoury mince + 2 small lamb chops = 2 servings

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-6 servings
- ◯ 7 or more servings

* 4. How often do you usually eat meat?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Beef mince dishes (rissoles, meatloaf, hamburger pattie) - 1 slice / patty / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Beef or veal mixed dishes (casserole, stir-fry) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Beef or veal (roast, chop, steak, schnitzel, corned beef) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lamb, hogget or mutton mixed dishes (stews, casserole, stir-fry) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Lamb, hogget or mutton (roast, chops, steak) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pork (roast, chop, steak) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned corned beef - 1 medium slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

* 5. How often do you usually eat these other meats?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Sausage, frankfurter or saveloy - 1 sausage / frankfurter/ 2 saveloys	◯	◯	◯	◯	◯	◯	◯	◯	◯
Bacon - 2 rashers	◯	◯	◯	◯	◯	◯	◯	◯	◯
Ham - 1 medium slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Luncheon meats or brawn - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯
Salami or chorizo - 1 slice / cube	◯	◯	◯	◯	◯	◯	◯	◯	◯
Offal (liver, kidneys, pate) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Venison/game - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

9. Poultry

* 1. Do you eat poultry e.g. chicken, turkey or duck?

- ◯ No
- ◯ Yes

* 2. Do you remove the skin from chicken? (Please choose one only)

- ◯ Not applicable
- ◯ Always
- ◯ Often
- ◯ Occasionally
- ◯ Never remove the skin from chicken

* 3. On average, how many servings of chicken do you eat per week? (Please choose one only)
(A 'serving' = palm size of chicken or ½ cup)
e.g. 1 chicken breast + 2 chicken drumsticks + 1 chicken thigh = 4 servings per week

- ◯ Not applicable
- ◯ Less than1 serving
- ◯ 1-3 servings
- ◯ 4-6 servings
- ◯ 7 or more servings

* 4. How often do you usually eat poultry?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Chicken legs or wings - palm size / ½ cup / 1 unit (wing, drumstick)	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chicken breast - palm size / ½ cup / ½ breast	◯	◯	◯	◯	◯	◯	◯	◯	◯
Chicken mixed dishes (casserole, stir-fry) - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Crumbed chicken (nuggets, patties, schnitzel) - 1 medium / 4 nuggets	◯	◯	◯	◯	◯	◯	◯	◯	◯
Turkey or quail - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mutton bird or duck - palm size / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

10. Fish and Seafood

* 1. Do you eat any type of fish or seafood?

- ◯ No
- ◯ Yes

* 2. On average, how many servings of fish and seafood (all types; fresh, frozen, tinned) do you eat per week? (Please choose one only)
(A ‘serving’ = 80 - 120g or palm size or small tin (85g))
e.g. 1 fish fillet and 1 small tin of tuna = 2 servings per week.

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-6 servings
- ◯ 7 or more servings

* 3. How do you normally cook / eat fish? (You can choose up to 3 options, but please only choose the ones you usually have)

- ☐ Not applicable
- ☐ Raw / I don’t cook it
- ☐ Oven baked / Grilled
- ☐ Deep fried
- ☐ Shallow fry
- ☐ Micro waved
- ☐ Steamed
- ☐ Poached
- ☐ Smoked

* 4. How often do you usually eat seafood?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Canned Salmon - 1 small can (85-95g)	○	○	○	○	○	○	○	○	○
Canned Tuna - 1 small can (85-95g)	○	○	○	○	○	○	○	○	○
Canned Mackerel, sardines, anchovies, herring - 1 small can (85-95g)	○	○	○	○	○	○	○	○	○
Frozen crumbed fish (patties, fillets, cakes, fingers, nuggets) - 1 medium / 4 nuggets	○	○	○	○	○	○	○	○	○
Snapper, Tarakihi, Hoki, Cod, Flounder - palm size / ½ cup	○	○	○	○	○	○	○	○	○
Gurnard, Kahawai or Trevally - palm size / ½ cup	○	○	○	○	○	○	○	○	○
Lemon fish or Shark - palm size / ½ cup	○	○	○	○	○	○	○	○	○
Tuna - palm size / ½ cup	○	○	○	○	○	○	○	○	○
Salmon, trout or eel - palm size / ½ cup	○	○	○	○	○	○	○	○	○

* 5. How often do you usually eat seafood?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Shrimp, prawn, lobster or crayfish - ½ cup	○	○	○	○	○	○	○	○	○
Crab or surumi - ½ cup	○	○	○	○	○	○	○	○	○
Scallops, mussels, oysters, paua or clams - ½ cup	○	○	○	○	○	○	○	○	○
Pipi or cockle - ½ cup	○	○	○	○	○	○	○	○	○
Kina - ½ cup	○	○	○	○	○	○	○	○	○
Whitebait - ¼ cup	○	○	○	○	○	○	○	○	○
Roe - ¼ cup	○	○	○	○	○	○	○	○	○
Squid, octopus, calamari, cuttlefish - ½ cup	○	○	○	○	○	○	○	○	○

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11. Fats and Oils

* 1. Do you cook meat, chicken, fish, eggs and/or vegetables with fat or oil?

- ○ No
- ○ Yes

* 2. What type(s) do you use most often? (You can choose up to 3 options, but please only choose the ones you usually have)

- [ ] Not applicable
- [ ] Butter (all varieties)
- [ ] Margarines (all varieties)
- [ ] Cooking oils (all varieties)
- [ ] Lard, Dripping, Coconut oil, Ghee (clarified butter)
- [ ] Cooking spray

Other (please state)

* 3. Chose the one you use the most

- [ ] Not applicable
- [ ] Butter (all varieties)
- [ ] Margarines (all varieties)
- [ ] Cooking oils (all varieties)
- [ ] Lard, Dripping, Coconut oil, Ghee (clarified butter)
- [ ] Cooking spray
- [ ] Other (please state)

* 4. When you use fat or oil to cook, how many servings of fat or oil do you use per dish? (Please choose one only)
(A 'serving' = 1 level teaspoon or 5 mL)

- ○ Not applicable
- ○ Less than 1 serving
- ○ 1 serving
- ○ 2 servings
- ○ 3 servings
- ○ 4 servings
- ○ 5 or more servings

* 5. On average, how many servings of fat or oil do you use to cook per week? (Please choose one only)

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1-3 servings
- ◯ 4-7 servings
- ◯ 8-10 servings
- ◯ 11-14 servings
- ◯ 15 or more servings

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12. Eggs

* 1. Do you eat eggs?

- ◯ No
- ◯ Yes

* 2. On average, not counting eggs used in baking / cooking, how many eggs do you usually eat per week? (Please choose one only)

- ◯ Not applicable
- ◯ Less than 1 egg
- ◯ 1 egg
- ◯ 2 eggs
- ◯ 3 eggs
- ◯ 4 eggs
- ◯ 5 or more eggs

* 3. How often do you usually eat eggs?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Whole eggs (hard-boiled, poached, fried, mashed, omelette, scrambled) - 1 egg	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mixed egg dish (quiche, frittata, other baked egg) - 1 slice	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

13. Legumes

* 1. Do you eat legumes e.g. chickpeas/dried peas, soybeans, dried/canned beans, baked beans, lentils or Dahl?

- ◯ No
- ◯ Yes

* 2. On average, how many servings of legumes (fresh, frozen, canned, dried) do you eat per week? (Please choose one only)
(A 'serving' = ½ cup or 125g of cooked legumes)

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1 serving
- ◯ 2 servings
- ◯ 3 servings
- ◯ 4-5 servings
- ◯ 6-7 servings
- ◯ 8 or more servings

* 3. How often do you usually eat these legumes?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Soybeans - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tofu - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Dahl - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Canned or dried legumes, beans (baked beans, chickpeas, lentils, peas, beans) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Hummus - 2 Tbsp	◯	◯	◯	◯	◯	◯	◯	◯	◯

EXPLORE Food Frequency Questionnaire

14. Vegetables

* 1. Do you eat vegetables?

- ◯ No
- ◯ Yes

* 2. On average, how many servings of vegetables (fresh, frozen, canned) do you eat per day? Do NOT include vegetable juices. (Please choose one only)
(A 'serving' = 1 medium potato / kumara or ½ cup cooked vegetables or 1/2 cup of lettuce)
e.g. 2 medium potatoes + ½ cup of peas = 3 servings

- ◯ Not applicable
- ◯ Less than 1 serving
- ◯ 1 serving
- ◯ 2 servings
- ◯ 3 servings
- ◯ 4 or more servings

* 3. How often do you usually eat these vegetables?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Potato (boiled, mashed, baked, roasted) - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Pumpkin (boiled, mashed, baked, roasted) - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Kumara (boiled, mashed, baked, roasted) - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mixed frozen vegetables - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Green beans - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Silver beet, spinach - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Carrots - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Sweet corn - 1 medium cob / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Mushrooms - ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Tomatoes - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Beetroot - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯
Taro, cassava or breadfruit - 1 medium / ½ cup	◯	◯	◯	◯	◯	◯	◯	◯	◯

* 4. How often do you usually eat these vegetables?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Green bananas (plantain) - 1 medium / ½ cup	○	○	○	○	○	○	○	○	○
Sprouts (alfalfa, mung) - ½ cup	○	○	○	○	○	○	○	○	○
Pacific Island yams - 1 medium / ½ cup	○	○	○	○	○	○	○	○	○
Turnips, swedes, parsnip or yams - ½ cup	○	○	○	○	○	○	○	○	○
Onions, celery or leeks - ¼ cup	○	○	○	○	○	○	○	○	○
Cauliflower, broccoli or broccoflower - ½ cup	○	○	○	○	○	○	○	○	○
Brussel sprouts, cabbage, red cabbage or kale - ½ cup	○	○	○	○	○	○	○	○	○
Courgette/zucchini, marrow, eggplant, squash, kamo kamo, asparagus, cucumber - ½ cup	○	○	○	○	○	○	○	○	○
Capsicum (peppers) - ½ medium / ¼ cup	○	○	○	○	○	○	○	○	○
Avocado - ¼ avocado	○	○	○	○	○	○	○	○	○
Lettuce greens (mesculin, cos, iceberg) - ½ cup	○	○	○	○	○	○	○	○	○
Other green leafy vegetables (whitloof, watercress, taro leaves, puha) - ½ cup	○	○	○	○	○	○	○	○	○

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15. Fruit

* 1. Do you eat fruit?

- ○ No
- ○ Yes

* 2. On average, how many servings of fruit (fresh, frozen, canned or stewed) do you eat per day? Do NOT include fruit juice. (Please choose one only)
(A 'serving' = 1 medium or 2 small pieces of fruit or 1/2 cup of chopped fruit)
e.g. 1 apple + 2 small apricots = 2 servings)

- ○ Not applicable
- ○ Less than one serving
- ○ 1 serving
- ○ 2 servings
- ○ 3 or more servings

* 3. How often do you usually eat these fruits?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Apple - 1 medium / ½ cup	○	○	○	○	○	○	○	○	○
Pear - 1 medium / ½ cup	○	○	○	○	○	○	○	○	○
Banana - 1 medium / ½ cup	○	○	○	○	○	○	○	○	○
Orange, mandarin, tangelo, grapefruit - 1 medium / 2 small	○	○	○	○	○	○	○	○	○
Peach, nectarine, plum or apricot - 1 medium / ½ cup / 2 small	○	○	○	○	○	○	○	○	○
Mango, paw-paw or persimmons / ½ cup	○	○	○	○	○	○	○	○	○
Pineapple - ½ cup	○	○	○	○	○	○	○	○	○
Grapes - ½ cup / 8-10 grapes	○	○	○	○	○	○	○	○	○
Strawberries, other berries, cherries - ½ cup	○	○	○	○	○	○	○	○	○
Melon (watermelon, rockmelon) - ½ cup	○	○	○	○	○	○	○	○	○
Kiwifruit - 1 medium / 2 small	○	○	○	○	○	○	○	○	○
Feijoas - 1 medium / 2 small	○	○	○	○	○	○	○	○	○
Tamarillos - 1 medium / ½ cup	○	○	○	○	○	○	○	○	○
Sultanas, raisins or currants - 1 small box	○	○	○	○	○	○	○	○	○
Other dried fruit (apricots, prunes, dates) - 4 pieces	○	○	○	○	○	○	○	○	○

EXPLORE Food Frequency Questionnaire

16. Drinks

* 1. On average, how many drinks do you have per day? (Please choose one only)
(A 'serving' = 250 mL or one cup/glass)

- ○ Less than 1 serving
- ○ 1-3 servings
- ○ 4-5 servings
- ○ 6-8 servings
- ○ 9-10 servings
- ○ 11 or more servings

* 2. How often do you usually have these drinks?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Instant soup (Cup of soup) - 250 mL / 1 cup	○	○	○	○	○	○	○	○	○
Fruit juice (Just Juice, Fresh-up, Charlie's, Rio Gold) - 250 mL / 1 cup/glass	○	○	○	○	○	○	○	○	○
Fruit drink (Choice, Rio Splice) - 250 mL / 1 cup/glass	○	○	○	○	○	○	○	○	○
Vegetable juice (tomato juice, V8 juice) - 250 mL / 1 cup/glass	○	○	○	○	○	○	○	○	○
Iced Tea (Lipton ice tea) - 250 mL / 1 cup/glass	○	○	○	○	○	○	○	○	○
Cordial or Powdered drinks (Thriftee, Raro, Vita-fresh) - 250 mL / 1 cup/glass	○	○	○	○	○	○	○	○	○
Low-calorie cordial - 250 mL / 1 cup/glass	○	○	○	○	○	○	○	○	○
Energy drinks small-medium can (V, Red Bull) - 250-350 mL	○	○	○	○	○	○	○	○	○
Energy drinks large can (Monster, Mother, Demon, large V) - 450-550 mL	○	○	○	○	○	○	○	○	○
Sugar-free Energy drinks (sugar-free V, Monster, Red Bull) - 1 small can	○	○	○	○	○	○	○	○	○
Diet soft/fizzy/carbonated drink (diet sprite) - 250 mL / 1 cup/glass	○	○	○	○	○	○	○	○	○
Soft/fizzy/carbonated drinks (Coke, Sprite) - 250 mL / 1 cup/glass	○	○	○	○	○	○	○	○	○
Sport's drinks (Gatorade, Powerade) - 1 bottle	○	○	○	○	○	○	○	○	○
Flavoured water (Mizone, H2Go flavoured) - 1 bottle	○	○	○	○	○	○	○	○	○
Water (unflavoured mineral water, soda water, tap water) - 250 mL / 1 cup/glass	○	○	○	○	○	○	○	○	○

* 3. How often do you usually have these drinks?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Coffee instant or brewed with or without milk (Nescafe, expresso) - 1 cup	○	○	○	○	○	○	○	○	○
Specialty coffees (flat white, cappuccino, lattes) - 1 small cup	○	○	○	○	○	○	○	○	○
Coffee decaffeinated or substitute (Inka) - 1 cup	○	○	○	○	○	○	○	○	○
Hot chocolate drinks (drinking chocolate, hot chocolate, Koko) - 1 cup	○	○	○	○	○	○	○	○	○
Milo - 1 tsp	○	○	○	○	○	○	○	○	○
Tea (English breakfast tea, Earl Grey) - 1 cup	○	○	○	○	○	○	○	○	○
Herbal tea or Green tea - 1 cup	○	○	○	○	○	○	○	○	○
Soy drinks - 1 cup	○	○	○	○	○	○	○	○	○

* 4. How often do you usually have these alcoholic drinks?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Beer – low alcohol - 1 can or bottle	○	○	○	○	○	○	○	○	○
Beer – ordinary - 1 can or bottle	○	○	○	○	○	○	○	○	○
Red wine - 1 small glass	○	○	○	○	○	○	○	○	○
White wine, champagne, sparkling wine - 1 small glass	○	○	○	○	○	○	○	○	○
Wine cooler - 1 small glass / bottle	○	○	○	○	○	○	○	○	○
Sparkling grape juice - 1 glass / cup	○	○	○	○	○	○	○	○	○
Sherry or port - 100 mL	○	○	○	○	○	○	○	○	○
Spirits, liqueurs - 1 shot or 30 mL	○	○	○	○	○	○	○	○	○
RTD (KGB, Vodka Cruiser, Woodstock bourbon) - 1 bottle / can	○	○	○	○	○	○	○	○	○
Cider - 1 glass / cup / bottle	○	○	○	○	○	○	○	○	○
Kava - 1 glass / cup	○	○	○	○	○	○	○	○	○

EXPLORE Food Frequency Questionnaire

17. Dressings and Sauces

* 1. How often do you usually have these dressings or sauces?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Butter (all varieties) - 1 tsp									
Margarine (all varieties) - 1 tsp									
Oil (all varieties) - 1 tsp									
Cream or sour cream - 1 Tbsp									
Mayonnaise or creamy dressings (aioli, tartae sauce) - 1 Tbsp									
Low fat/calorie dressing (reduced fat mayonnaise) - 1 Tbsp									
Salad dressing (french, italian) - 1 Tbsp									
Sauces (tomato, BBQ, sweet chilli, mint) - 1 Tbsp									
Mustard - 1 Tbsp									
Soy sauce - 1 Tbsp									
Chutney or relish - 1 Tbsp									
Gravy homemade - ¼ cup									
Instant Gravy (e.g. Maggi) - ¼ cup									
White sauce/cheese sauce - ¼ cup									

EXPLORE Food Frequency Questionnaire

18. Miscellaneous - Cakes, Biscuits and Puddings

* 1. How often do you usually eat these baked products?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Cakes, loaves, sweet muffins - 1 slice / 1 muffin									
Sweet pies or pastries, tarts, doughnuts - 1 medium									
Other puddings or desserts - not including milk-based puddings (sticky date pudding, pavlova) - ½ cup									
Plain biscuits, cookies (Round wine, Ginger nut) - 2 biscuits									
Fancy biscuits (chocolate, cream) - 2 biscuits									

EXPLORE Food Frequency Questionnaire

19. Miscellaneous

* 1. How often do you usually eat these other foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Jelly - ½ cup	○	○	○	○	○	○	○	○	○
Ice blocks - 1 ice block	○	○	○	○	○	○	○	○	○
Lollies - 2 lollies	○	○	○	○	○	○	○	○	○
Chocolate - including chocolate bars (Moro bars) - 1 small bar	○	○	○	○	○	○	○	○	○
Sugar added to food and drinks - 1 level tsp	○	○	○	○	○	○	○	○	○
Jam, honey, marmalade or syrup - 1 level tsp	○	○	○	○	○	○	○	○	○
Vegemite or marmite - 1 level tsp	○	○	○	○	○	○	○	○	○
Peanut butter or other nut spreads - 1 level Tbsp	○	○	○	○	○	○	○	○	○
Brazil nuts or walnuts - 2	○	○	○	○	○	○	○	○	○
Peanuts - 10	○	○	○	○	○	○	○	○	○
Other nuts (almonds, cashew, pistachio, macadamia) - 10	○	○	○	○	○	○	○	○	○
Seeds (pumpkin, sunflower)	○	○	○	○	○	○	○	○	○
Muesli bars - 1 bar	○	○	○	○	○	○	○	○	○
Coconut cream - ¼ cup	○	○	○	○	○	○	○	○	○
Coconut milk - ¼ cup	○	○	○	○	○	○	○	○	○
Lite coconut milk - ¼ cup	○	○	○	○	○	○	○	○	○
Potato crisps, corn chips, Twisties - ½ cup / handful	○	○	○	○	○	○	○	○	○

* 2. Do you use salt in cooking?

- ○ Never
- ○ Rarely
- ○ Sometimes
- ○ Usually
- ○ Always

* 3. Do you use salt at the table?

- ◯ Never
- ◯ Rarely
- ◯ Sometimes
- ◯ Usually
- ◯ Always

EXPLORE Food Frequency Questionnaire

20. Miscellaneous - Takeaways

* 1. On average, how often do you eat takeaways per week? (Please choose one only)

- ◯ Never
- ◯ Less than 1 times
- ◯ 1-2 times
- ◯ 3-4 times
- ◯ 4-6 times
- ◯ More than 7 times

* 2. How often do you usually eat these takeaway foods?

	Never	<1x / month	1-3x / month	1x / week	2-3x / week	4-6x / week	Once / day	2-3x / day	4+ x / day
Meat pie, sausage roll, other savouries - 1 pie / 2 small sausage rolls or savouries	○	○	○	○	○	○	○	○	○
Hot potato chips, kumara chips, french fries, wedges - ½ cup	○	○	○	○	○	○	○	○	○
Chinese - 1 serve	○	○	○	○	○	○	○	○	○
Indian - 1 serve	○	○	○	○	○	○	○	○	○
Thai - 1 serve	○	○	○	○	○	○	○	○	○
Pizza - 1 medium slice	○	○	○	○	○	○	○	○	○
Burgers - 1 medium burger	○	○	○	○	○	○	○	○	○
Battered fish - 1 piece	○	○	○	○	○	○	○	○	○
Fried chicken (KFC, Country fried chicken) - 1 medium piece	○	○	○	○	○	○	○	○	○
Bread based (Kebab, sandwiches, wraps, Pita Pit, Subway) - 1 medium	○	○	○	○	○	○	○	○	○

EXPLORE Food Frequency Questionnaire

21. Other

* 1. Are there any other foods or drinks that you can think of that you have on a regular basis that was not covered by this questionnaire?

- ○ No
- ○ Yes

EXPLORE Food Frequency Questionnaire

22. Other

1. Please list these foods and drinks including; the serving size, and how many times per week you eat or drink these items (e.g. Pizza, 4 slices, one time per week)

Appendix C: Asia Pacific Journal of Clinical Nutrition Author Guide

Instructions for Authors

(Revised September 2017)

AIMS AND SCOPE

The aims of the *Asia Pacific Journal of Clinical Nutrition* (*APJCN*) are to publish high quality clinical nutrition relevant research findings which can build the capacity of clinical nutritionists in the region and enhance the practice of human nutrition and related disciplines for health promotion and disease prevention. *APJCN* will publish original research reports, reviews, short communications and case reports. News, book reviews and other items will also be included. The acceptance criteria for all papers are the quality and originality of the research and its significance to our readership. Except where otherwise stated, manuscripts are peer-reviewed by at least two anonymous reviewers and the Editor. The Editorial Board reserves the right to refuse any material for publication and advises that authors should retain copies of submitted manuscripts and correspondence as material cannot be returned. Final acceptance or rejection rests with the Editorial Board.

Short Communications about special group or region- al diets, nutrition and health

It is the APJCN policy and approach to descriptive studies, which record and monitor special group, local or regional food habits, nutritional status and their health relevance, to provide a short communication option. Studies which may be considered would be well-designed and conducted, with a representative and adequate sample to allow for generalisability to the purported groups studied. Such publications need to satisfy the following criteria: (1) Brevity, with no more than 3 tables or figures to succinctly present foods, nutrients and health (not longer than 3 pages of the Journal including references) (2) Novel and not simply repetitive of what others have done, although documentation of adverse or favourable trends is encouraged (3) Problem-solving in approach. These papers will be published as an identifiable section of an issue "Short Communications about Asia Pacific Food Patterns and their Health Relevance".

SUBMISSION OF MANUSCRIPTS

All articles submitted to the journal must comply with these instructions. Failure to do so will result in return of the manuscript and possible delay in publication. Manu- scripts should be written so that they are intelligible to the professional reader who is not a specialist in the particular field. Where contributions are judged as acceptable for publication on the basis of scientific content, the Editor or the Publisher reserve the right to modify typescripts to eliminate ambiguity and repetition and improve communication between author and reader. If extensive alterations are required, the manuscript will be returned to the author for revision. Authors are advised to have their manuscripts reviewed by a scientific colleague who is fluent in English so that the manuscripts will conform to English usage and grammar.

Attribution of Authorship

The editors and readership need reassurance that the scholarship required of a scientific paper in APJCN has been duly executed and recognized by the stated author- ship.

Authors should have regard to the following steps and contributions ordinarily required to develop, execute and report a scientific project (specify in the **Title page**):

- • Conception and design
- • Doing the field, experimental, clinical, data collection or compilation work, provided there is also a scholarly input during the process
- • Data analysis and interpretation
- • Preparation of draft manuscript, doing revisions or providing critique

- • Overall and/or sectional scientific management

If the contributions are of a more technical or secretarial nature than intellectual or scholarly, they can be acknowledged as a final footnote to the paper in the usual way. However, this note should be brief and represent significant input without which the work would not have materialized.

APJCN acknowledges only one first author and one corresponding author. The corresponding author assumes contractual responsibility for all arrangements between the Journal and the authors while all authors remain collectively responsible for the scientific integrity of the pa- per.

Covering letter

Papers are accepted for publication in the journal on the understanding that the content has not been published or submitted for publication elsewhere; a statement indicating the paper's originality should be included. This must be part of the covering letter. Authors must also state that the protocol for the research project has been approved by a suitably constituted Ethics Committee of the institution within which the work was undertaken and that it con- forms to the provisions of the Declaration of Helsinki in 1995 (as revised in Edinburgh 2000). All investigations on human subjects must include a statement that the subject gave informed consent and patient anonymity should be preserved. Any experiments involving animals must be demonstrated to be ethically acceptable and where relevant conform to National Guidelines for animal usage in research. Details of at least 4 potential referees.

Submission

The manuscript and other required documents including a completed Copyright Assignment Form and a list of four potential referees (see below) should be uploaded through

Professor Duo Li

Editor-in-Chief
Asia Pacific Journal of Clinical Nutrition

Once the manuscript has reached our Editor, normally the corresponding author will be informed by email within a week. When the review process (between 1 and 4 months) is completed, we will send by email a note of acceptance or non-acceptance for publication of the manuscript.

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Potential referees

Authors are required to provide at least 4 potential referees, with affiliations and addresses, including email addresses. At least two of the referees should work or reside in a country other than that of the authors, and none should come from any of the authors' own institutions. We do not necessarily use your recommended referees. The onus is on all authors of a submission to ensure that selected referees are not in a conflict of interest likely to result in an un-objective peer review report.

Proof of scientific English standard

To ensure the quality of the manuscript, manuscripts should be professionally edited for scientific English. Certificate for manuscripts that underwent professional editing services should be provided prior to submission to APJCN. A discount service of Wallace editing (http://www.editing.tw/en/en) is available for those who are submitting their manuscripts to APJCN.

PREPARATION OF THE MANUSCRIPT

Format your manuscript for ISO A4 (212 _ 297 mm) with margins of 2.5 cm; use double-spacing and Times New Roman 12-point font size throughout by computer software WORD. The abstract and text pages should have line numbers in the left margin. All pages should be numbered consecutively in the top right-hand corner, be- ginning with the title page. Indent new paragraphs. Turn the hyphenation option off, including only those hyphens that are essential to the meaning.

Style

Manuscripts should follow the style of the Vancouver agreement detailed in the 'Uniform Requirements for Manuscripts Submitted to Biomedical Journals', as presented in JAMA 1997;277:927–34 (www.acponline.org/ journals/anals/01jan97/unifreqr.htm). *APJCN* uses US/ UK spelling and authors should therefore follow the latest edition of the Merriam–Webster's Collegiate Dictionary/Concise Oxford Dictionary. Please indicate your preference and use one or the other exclusively. If you do not specify, by default UK spelling will be used. A Guide for Medical and Scientific Editors and Authors (Royal Society of Medicine Press, London). Abbreviations should be used sparingly and only where they ease the reader's task by reducing repetition of long, technical terms. Initially use the word in full, followed by the abbreviation in parentheses. Thereafter use the abbreviation. At the first mention of a chemical substance, give the generic name only. Trade names should not be used. Drugs should be referred to by their generic names, rather than brand names.

For vitamins, notation use is B-2, B-2, B-3, B-6 and B- 12 not B_1, B_2, B_3, B_6 and B_{12}. "Fetal" is more etymologically correct than "Foetal".

Note style for probability: $p<0.01$, with a lower-case letter *p*. Avoid reporting an excessive number of digits beyond the decimal for estimates. They may alternatively be reported as less than some specified value (eg, $p<0.05$ or $p<0.001$).

Parts of the manuscript

Present your manuscript in the following order: (1) title page, (2) abstract and keywords, (3) text, (4) acknowledgements, (5) conflict of interest and funding disclosure, (6) references, (7) figure legends, (8) tables (each table complete with title and footnotes) and (9) figures. Foot- notes to the text are not allowed and any such material should be incorporated into the text as parenthetical mat- ter. Save and submit the above materials in **one** single Word file only.

Please do not use "level" when "concentration" is in- tended; or "life style" when "personal behaviour" is meant. Prefer "men" and "women" to "male" and "female".

Title page

The title page should contain (1) the title of the paper, which should be short, informative and contain the major key words, (2) a short running title (less than 50 characters, including spaces), (3) the full name (given name, middle initial, if any, and family name in that order) of each author along with principal qualification, email ad- dress and **individual contribution** (4) the addresses of the institutions at which the work was carried out together with (5) the full postal and email, and alternate email (to ensure email contact at all times) address, plus facsimile and telephone numbers, of the author to whom correspondence about the manuscript, proofs and requests for offprint should be sent.

Note: Names and principal qualification of authors should be presented as follow:
John Doe PhD[1], Mary Jane MSc[2]

Abstract and key words

The abstract should be structured with Background and Objectives, Methods and Study Design, Results, and Conclusions in 250 words or less. The abstract should not contain abbreviations or references. Five key words should be supplied below the abstract.

Text

Authors should use subheadings to divide the sections of their manuscript:
INTRODUCTION, MATERIALS AND METHODS, RESULTS, DISCUSSION, ACKNOWLEDGMENTS, REFERENCES.

Numerical results and *p* values should be presented in text, tables and figures with no more than **3 significant figures**, unless there are exceptional circumstances.
Examples would be:

52.37 kg which should be 52.4 kg
p=0.15234 which should be p=0.152
Authors can make a case that their methodology re-

quires further exception to these guidelines.

Methods

All manuscripts should provide the **clinical trial registration number** (if applicable). **Ethical approval number** should also be stated in the manuscript along with a statement in regards to the informed consent of participants in all trials.

Acknowledgements

Technical assistance and advice may be acknowledged in this section.

Conflict of Interest and Funding Disclosure

Authors should declare any financial support or relation- ships that may pose a conflict of interest. The source of financial grants and other funding should be acknowledged, including a frank declaration of the authors' industrial links and affiliations.

References

APJCN uses the Vancouver system for referencing. In the text, references should be cited using superscript Arabic numerals, after comma or full stop, in the order in which they appear, eg 'There is increasing recognition of antecedents of chronic disease like diabetes and cardiovascular disease in early life.[1,2] If cited only in tables or figure legends, number them according to the first identification of the table or figure in the text. In the reference list, the

references should be numbered and listed in order of appearance in the text. Cite the names of all authors. When an article has more than ten authors, only the names of the first six authors should be given followed by 'et al'. The issue number should be omitted if there is continuous pagination throughout a volume. Names of journals should be abbreviated in the style used in Index Medicus (ftp://nlmpubs.nlm.nih.gov/online/journals/ljiweb.pdf). Reference to unpublished data and personal communications should appear in the text only. Please consult http:// www.nlm.nih.gov/bsd/uniform_requirements.html for detail. If you use EndNote to manage bibliography, you can download the APJCN citation style from our website (www.apjcn.org) and locate the copy under your End- Note/styles. Some examples are listed as follows:

Journal article

1. Zarrin R, Ibiebele TI, Marks GC. Development and validity assessment of a diet quality index for Australians. Asia Pac J Clin Nutr. 2013;22:177-87. doi: 10.6133/apjcn.2013.22.2.15.
2. Weiss R, Dziura J, Burgert TS, Tamborlane WV, Taksali SE, Yeckel CW et al. Obesity and the metabolic syndrome in children and adolescents. N Engl J Med. 2004;350:2362-74. doi: 10.1056/Nejmoa031049.

Book

3. Fildes VA. Breasts, bottles, and babies. A history of infant feeding. Edinburgh: Edinburgh University Press; 1986.

Chapter in a Book

4. Willett W. The use of biomarkers in nutritional epidemiology. In: Kok F, Veer P, editors. Biomarkers of dietary exposure. London: Smith-Gordon; 1991. pp. 9-14.

Internet linkage

5. Mahowald ML. Overview of the evaluation and manage- ment of gout and hyperuricemia. Rheumatology & Musculoskeletal Medicine for Primary Care, Gout. 2004/10/8 [cited 2005/5/12]; Available from: http://www.rheumatology.org/ publications/primarycare/number4/hrh0021498.asp
6. Talukder A, Haselow NJ, Osei AK, Villate E, Reario D, Kroeun H et al. Homestead food production model contributes to improved household food security and nutrition status of young children and women in poor populations. Les- sons learned from scaling-up programs in Asia (Bangladesh, Cambodia, Nepal and Philippines). 2000/2/17 [cited 2012/8/6]; Available from: http://factsreports.revues.org/404.

Tables

Tables should be self-contained and complement, but not duplicate, information contained in the text. Each table must be formatted by using the table feature in WORD and presented as a separate file with a comprehensive but concise heading. Tables should be numbered consecutively in Arabic numerals in the sequence in which they are mentioned in the text. Use a single top rule, a single rule below the headings, and a single bottom rule. Do not use rules within the table body. Column headings should be clearly delineated, with straddle rules over pertinent columns to indicate subcategories. Column headings should

be brief, with units of measurement in parentheses; all abbreviations should be defined in footnotes. Footnote symbols: †, ‡, §, ¶, ††, should be used (in that order) and *, **, *** should be reserved for ***p*** values. The table and its legend/ footnotes should be understandable without reference to the text. All lettering/ numbers used in tables should be font style 'Times New Roman' and font size 8.5 or 9.

Figures

All illustrations (line drawings, bar charts and photo- graphs) are classified as figures. Figures should be cited in consecutive order in the text. Figures should be sized to fit within the column (85 mm), intermediate (114 mm) or the full text width (177 mm). Line figures or bar chart figures should be drawn in a computer graphics package (e.g. EXCEL, Sigma Plot, SPSS etc.). All lettering used in figures should be font style 'Times New Roman' and font size 9.

Important: All figures must be electronically inserted at the end of the manuscript. Photographs should be supplied as 300 dpi or more, black and white photographic prints and must be unmounted. Individual photographs forming a composite figure should be of equal contrast, to facilitate printing, and should be accurately squared. Photographs need to be cropped sufficiently to prevent any subject being recognized, or an eye bar used; otherwise, written permission to publish must be obtained. Colour photographs should be submitted digitally with the pixel characteristics of good quality, for on-line publication. Where hard copy colour is required, a charge of AU$1,100/US$660 for the first three colour figures and AU$550/US$330 for each extra colour figure thereafter will be charged to the author.

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Abbreviations

The following abbreviations are accepted without definition by APJCN

ANCOVA (analysis of covariance) ANOVA (analysis of variance) BMI (body mass index)
BMR (basal metabolic rate)

CHD (coronary heart disease) CI (confidence interval)
CVD (cardiovascular disease) df (degrees of freedom)

DHA (docosahexaenoic acid) DNA (deoxyribonucleic acid) DRIs (dietary reference intakes)

EDTA (ethylenediamine tetra-acetic acid)
ELISA (enzyme-linked immunosorbent assay)
EPA (eicosapentaenoic acid)
FAO (Food and Agriculture Organization) (except when used as an author)
FFQ (food-frequency questionnaire)
GC (gas chromatography)
Hb (haemoglobin)
HDL (high-density lipoprotein)
HIV (human immunodeficiency virus)
HPLC (high-performance liquid chromatography)
IHD (ischaemic heart disease)
LDL (low-density lipoprotein)
MRI (magnetic resonance imaging)
MUFA (monounsaturated fatty acids)
NS (not significant)
OR (odds ratio)
PCR (polymerase chain reaction)
PUFA (polyunsaturated fatty acids)
RDA (recommended dietary allowance)
RER (respiratory exchange ratio)
RIA (radioimmunoassay)
RMR (resting metabolic rate)
RNA, mRNA etc. ribonucleic acid, messenger RNA etc.
SFA (saturated fatty acids)
SNP (single nucleotide polymorphism)
UN (United Nations) (except when used as an author)
UNICEF (United Nations International Children's Emergency Fund)

UV (ultra violet)
VLDL (very-low-density lipoprotein)
WHO (World Health Organization) (except when used as an author)