Development and validation of the New Zealand Women's Healthy Diet Index

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Abstract

Background: Diet quality indices represent an alternative approach to assessing associations between diet, health, and disease. At present, there is no simple, valid, food-based diet quality index to reflect the adherence of young women to national dietary guidelines in New Zealand

Aim: To develop and validate a healthy diet index to assess diet quality and adherence of young women to the Eating and Activity Guidelines for New Zealand Adults (EAGNZA).

Method: Dietary information was obtained from young women (n=110) aged 19 – 45 years who completed the New Zealand Women's Food Frequency Questionnaire (NZWFFQ). Data from the NZWFFQ was used to develop the New Zealand Women's Healthy Diet Index (NZW-HDI). Participants also completed a four-day weighed food record (FR), which was used to validate the index. Relative validity was evaluated by comparing the NZW-HDI total scores derived from the NZWFFQ against the NZW-HDI derived from the FR. Paired t-tests, Pearson's correlation coefficients, cross-classification, and weighted kappa were used to assess relative validity. Construct validity of the NZW-HDI was determined using nutrient intakes from the FR and Spearman's correlation coefficients and linear contrast analysis.

Results: Participants achieved an average total score of 76.7 ± 0.9 for the NZW-HDI derived from the NZWFFQ and 75.2 ± 11.1 derived from the FR. For relative validity, a significant correlation between total scores from the NZWFFQ derived NZW-HDI and the FR derived NZW-HDI (r = 0.29; P < 0.05) was found. Cross-classification of participants showed 50% were classified into the same tertile, and 16% were grossly misclassified into opposite tertiles. The weighted κ-statistic found both methods had fair agreement in ranking the NZW-HDI total score (κ = 0.244). For construct validity, the NZW-HDI total score was significantly and positively related to dietary fibre (0.227), vitamin C (0.214), folate (0.286), and calcium intakes (0.277), and inversely related to intakes of saturated fat (-0.318) and alcohol (-0.236) (all p<0.05). In addition, using linear contrast analysis, higher NZW-HDI scores were associated with higher intakes of vitamin C and folate (P < 0.05).

Conclusion: Adherence to the EAGNZA was moderate in this sub-sample of participants. The NZW-HDI was found to have fair relative validity in assessing diet quality. As expected, the total score was positively associated with dietary fibre, vitamin C, folate, and calcium intakes, and inversely related to intakes of saturated fat and alcohol. Future research is required to improve the validity of the NZW-HDI before use in larger study populations.

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Abbreviations

Alternate Healthy Eating Index	A-HEI
Australian Eating Survey Food Frequency Questionnaire	AES FFQ
Australian Health Eating Index	Aust-HEI
Australian Recommended Food Score	ARFS
Body Mass Index	BMI
Bioelectrical Impedance Analysis	BIA
Coronary Heart Disease	CHD
Cardiovascular Disease	CVD
Canadian Healthy Eating Index	Canadian-HEI
Dietary Guidelines Index	DGI
Dietary Guidelines for Americans Index	DGAI
Diet Quality Index	DQI
Diet Quality Indices	DQIs
Diet Quality Index Alternative	DQI-a
Diet Quality Index China	DQI-C
Diet Quality Index Revised	DQI-R
Dietary Quality Score	DQS
Eating and Activity Guidelines for New Zealand Adults	EAGNZA
Examining Predictors Linking Obesity Related Elements	EXPLORE
Food Based Dietary Guidelines	FBDG
Food Frequency Questionnaire	FFQ
Food Habits Questionnaire	FHQ
Food Record	FR
Healthy Diet Indicator	HDI
Healthy Eating Index	HEI

Healthy Eating Index – 2005	HEI-2005
Healthy Eating Index – 2010	HEI-2010
Healthy Eating Index for Australian adults	HEIFA-2013
Healthy Food Index	HFI
Healthy Food and Nutrient Index	HFNI
Human Nutrition Research Unit	HNRU
Low-Density Lipoproteins	LDL
New Zealand	NZ
Nutrient Reference Values	NRVs
New Zealand Adolescent Food Frequency Questionnaire	NZAFFQ
New Zealand Women's Food Frequency Questionnaire	NWFFQ
New Zealand Diet Quality Index for Adolescents	NZDQI-A
New Zealand Women's Healthy Diet Index	NZW-HDI
Mediterranean Diet Score	MDS
Overall Dietary Index Revised	ODI-R
Recommended Food Score	RFS
Saturated Fat	SF
Simple Diet Quality Index	SDQI
Standard Deviation	SD
The Index of Relative Socioeconomic Disadvantage	SEIFA
United States	US
United States Department of Agriculture	USDA

1. Introduction

A high quality diet is one that is healthy, balanced, and adheres to dietary guidelines (Elmadfa & Meyer, 2012). As diet has been established as one of the most modifiable factors in health and disease (Ibiebele et al., 2009), a nutritious diet can prevent chronic diseases such as obesity, Type 2 diabetes, and cardiovascular disease (Alwan, 2011; Must et al., 1999). In order to establish dietary components that play a role in health and disease, dietary assessment methods are required to establish dietary intake (Shim, Oh, & Kim, 2014).

Dietary assessment methods are the primary tools of nutritional research to assess dietary intake. Conventional methods used to measure dietary intake quantitatively include food records and the 24-hour recall (Biro, Hulshof, Ovesen, & Amorim, 2002). These commonly used methods provide an accurate measure of nutrient intake (Gibson, 2005). Detailed information is gathered relating to diet including portion sizes, food preparation, and cooking methods (Shim et al., 2014). However, these methods can be time consuming and expensive (Massari, Freeman, Seccareccia, Menotti, & Farchi, 2004). Another approach is the use of retrospective dietary information from a diet history or food frequency questionnaire (Biro et al., 2002). These explore dietary intake over a longer period of time, ranging from days to years (Gibson, 2005; Jacques & Tucker, 2001). The main challenge associated with this approach is the inability to accurately estimate nutrient intake (Thompson & Subar, 2008). When investigating the dietary intake of large populations, it is essential that methods to assess dietary intake are accurate, efficient, and validated (Toft, Kristoffersen, Lau, Borch-Johnsen, & Jørgensen, 2007).

Previously, dietary intake from traditional dietary assessment methods has been translated into individual foods or nutrients (Hu, 2002). This has allowed the link between diet and disease to be evaluated by demonstrating that not only a specific nutrient deficiency, but also an excessive intake of a single nutrient or food, can have adverse effects on health and disease (Willet, 1998). While invaluable research has been gained from the reductionist approach, several limitations exist including: people do not consume foods or nutrients in isolation, but instead foods and food combinations (i.e. meals) containing a variety of nutrients that interact (Hu, 2002; McNaughton, Ball, Crawford, & Mishra, 2008); associations between single nutrients may be too small to detect alone, however the combined effects of nutrients and foods together (such as dietary patterns) may be more apparent (Hu, 2002; Newby & Tucker, 2004); statistically significant associations may occur by chance when investigating a number of nutrients or foods (Hu, 2002); the high level of nutrient correlation makes it difficult analyse each effect separately (Hu, 2002; Kourlaba & Panagiotakos,

2009a); and finally the effects of individual nutrients and foods may be confounded by dietary patterns (Hu, 2002).

Dietary patterns are an emerging trend that take a holistic approach to health (Waijers, Feskens, & Ocké, 2007; Wong, Parnell, Howe, Black, & Skidmore, 2013). They consider the whole diet, and factors such dietary behaviour, food variety and food choice, which all ultimately determine nutrient intake (Kennedy, Ohls, Carlson, & Fleming, 1995; Waijers et al., 2007). This notion has aided in the identification of healthy and unhealthy dietary patterns (Huijbregts et al., 1997). For example, the Dietary Approaches to Stop Hypertension (DASH) trial found that a diet abundant in fruit, vegetables, and whole grains with a low amount of fat and meat reduced blood pressure (Sacks et al., 2001). Food consumption patterns show a more powerful effect on health and disease than nutrients alone, as dietary patterns have been shown to track through a lifetime, and are a better representation of how people eat (Osler, Heitmann, Gerdes, Jørgensen, & Schroll, 2001).

Two distinct methods used to derive dietary patterns have been established. Firstly, defined dietary patterns use statistical techniques such as factor and cluster analysis. To establish dietary patterns, food consumption data (e.g. from a FFQ, food record) is used to generate meaningful results on eating patterns (Moeller et al., 2007; Waijers & Feskens, 2005). Secondly, diet quality indices (DQI) are theoretically defined and capture dietary patterns in a single exposure (Fransen & Ocke, 2008; Reedy et al., 2014). DQIs provide a summary measure to the quality of an individual's diet. A summary score is produced, which is made up of nutritional components that can be a combination of nutrients, food, and food groups. These components conceptualise what constitutes a healthy diet using predefined criteria (Preedy, Hunter, & Patel, 2013; Wong et al., 2013).

Indices of diet quality allow the extent to which individuals adhere to dietary guidelines, or a diet known to be beneficial to health such as the Mediterranean diet, to be measured (Wong et al., 2013). With respect to indices based on dietary guidelines, a broad range of indices have been developed. The most commonly used DQIs are the Diet Quality Index and Healthy Eating Index, which are based on United States (US) dietary guidelines (Kennedy et al., 1995; Patterson, Haines, & Popkin, 1994). Although the majority of indices have been produced in the United States, others have been adapted, modified, or newly developed in other Western countries (Waijers & Feskens, 2005). These tools have become a practical and valuable tool for public health. This is because DQIs can be used to monitor dietary changes, improve nutrition promotion, and predict health and disease outcomes (Kennedy et al., 1995; McCullough et al., 2000; Wirt & Collins, 2009). Moreover, as DQIs can be based on dietary guidelines, they can be translated into dietary advice, making it easier for the public to comprehend (Reedy et al., 2014).

Findings from the 2014/15 New Zealand Adult Nutrition Survey showed the prevalence of obesity has risen among females, and obesity is more common in women (32%) compared with men (29%) (Ministry of Health, 2015a). The growing rates of obesity are caused by a negative shift in energy balance (University of Otago and Ministry of Health, 2011b), due to a trend towards energy dense, nutrient poor foods (e.g. chocolate, sugar sweetened beverages, hot chips, and takeaways) and a lack of physical activity (Swinburn & James, 2004). A diet high in refined, processed food not only increases energy intake but also displaces foods that have a higher nutritive value (Lichtenstein et al., 2006). This is evidenced by a diet high in saturated fat and a lack of dietary fibre, and the fact that fewer women meet the recommended intake for fruit and vegetables (University of Otago & Ministry of Health, 2011).

There is also concern regarding micronutrient adequacy of females in New Zealand (NZ). It is well known that young premenopausal women are more at risk of iron deficiency because of menstruation, but also insufficient dietary intake (Heath, Skeaff, Williams, & Gibson, 2001). Beck et al (2013) observed associations between a low 'meat and vegetable' intake, or high 'milk and yoghurt' intake, and an increased risk of suboptimal iron status. In New Zealand, iron deficiency is prevalent in 5–12% of females aged 15–50 years. Within this subset, inadequate calcium intake is more common, with 56-88% not meeting the recommended daily intake (University of Otago and Ministry of Health, 2011b). As calcium and iron are vital nutrients for maternal health (Haines, Siega-Riz, & Popkin, 1999), fetal programming also highlights the importance of a healthy diet in young women. Poor nutrition in women of childbearing age has the potential to create a cycle of adverse effects on the health of subsequent offspring (Reifsnider, 2003). Therefore, women need to maintain an optimal nutritional status before, during, and between pregnancies, as an optimal diet quality preconception promotes favourable pregnancy outcomes (Mathews, Johnson, & Neil, 2008).

Although information on nutrient intakes and dietary sources of females living in NZ is available (Ministry of Health, 2003), there is no diet quality index specific to young women that allows the quality of the diet to be measured. As previously mentioned, various diet indices have been developed overseas. However, these DQIs would each have a distinct dietary pattern different to the NZ context (Wong et al., 2013), making it difficult to extrapolate. Diet quality indices should be country specific and relate to national dietary guidelines (Bazelmans et al., 2006; McNaughton et al., 2008). To gain further insight into dietary patterns, DQIs should consider food availability, and local foods unique to societal culture (Collins et al., 2015). Furthermore, there are a limited number of indices that are solely food based and do not include nutrients as components (McNaughton et al., 2008). Currently, the New Zealand Diet Quality Index for Adolescents (NZDQI-A) is the only DQI that

has been developed for use in a NZ population (Wong et al., 2013). The index is designed for adolescents, which hinders its use and application on an adult population, let alone young women. This is because differences lie between adolescents and adults in terms of food preference, energy and nutrient intake, nutrient recommendations and dietary guidelines (University of Otago and Ministry of Health, 2011b; Wong et al., 2013).

In the development of a new index, the validation process is important as it confirms that the index measures what it is proposed to measure (Gibson, 2005; Thompson & Subar, 2008). Three different types of validation methods used for DQIs have been identified in the literature. Content validity depends on whether the instrument represents all dimensions of content that it was supposed to measure. Construct validity investigates what qualities a tool corresponds to its theoretical concepts (Kaplan, Bush, & Berry, 1976). And lastly, relative (or criterion) validity is assessed by comparing the outcome of an instrument to a standard accepted as truth (Kaplan et al., 1976; Streiner, Norman, & Cairney, 2014). The majority of indices used construct validity, examining the associations of DQIs with characteristics such as food and nutrient intake (Kant, 1996). Only a few indices have measured relative validity, the primary choice of determining the validity of dietary assessment methods (Gibson, 2005). In order to determine the usefulness of the index for measuring overall diet quality, DQIs need to be compared to an independent reference method (e.g. food record) that has few correlated errors (Cade, Thompson, Burley, & Warm, 2002; Willet, 1998). Unfortunately, most DQIs available use the same dietary assessment method used to create the index to assess validity (Toft et al., 2007).

The Food and Nutrition Guidelines are the cornerstone of nutrition policy in New Zealand (Ministry of Health, 2003). These food based guidelines are population specific, therefore the guidelines are determined by nutrient needs for different life stages (Wardlaw, 2013). The purpose of these guidelines is to translate evidence-based recommendations into healthy eating advice for the consumer (European Food Safety Authority, 2010), as well as to be utilised by health professionals as an educational resource (Ministry of Health, 2015b). Recently, the Ministry of Health have released the new Eating and Activity Guidelines for New Zealand Adults (EAGNZA) (Ministry of Health, 2015b). It is therefore timely to develop a tool to assess the adherence of NZ women to the dietary guidelines, and whether this represents overall diet quality.

There is a warrant for a validated, food based, and population specific diet quality index for young women in New Zealand. A simple and valid tool based on the new EAGNZA is needed, which is easy for both health professionals and the consumer to understand. This will allow overall diet quality to be assessed and the adherence of young women to the dietary guidelines to be measured.

1.2 Aims and objectives

Aim

To develop and validate a healthy diet index as an indicator of diet quality in young women aged 19 – 45 years living in New Zealand.

Objectives

- To develop a healthy diet index based on the Eating and Activity Guidelines for New Zealand Adults
- To examine the adherence of young women to the Eating and Activity Guidelines for New Zealand Adults using data obtained from a food frequency questionnaire
- To assess the relative validity of the healthy diet index using data collected from four-day food records
- To determine the construct validity of the healthy diet index using nutrient intakes derived from four day food records

1.3 Thesis structure

This study has been structured into five chapters. Chapter one introduces the research topic and highlights the purpose of the study. The second chapter consists of the review of the literature relevant to the research topic. Following this, the third chapter details and justifies the methodology used to develop and validate the NZW-HDI. Chapter four contains the results of the study. Lastly, chapter five includes the discussion, conclusion, and recommendations for future research on diet quality indices.

1.4 Researcher's contribution to study

Table 1.1 Contribution of Researcher's to study

Researchers	Contributions to the thesis
Andrea Fenner	Main researcher; developed NZW-HDI and scoring criteria; involved in participant recruitment, screening, and testing; data entry and analysis; statistical analysis; interpretation and discussion of results; author of thesis
Dr Kathryn Beck	Main academic supervisor; development of study design, development of NZW-HDI and scoring criteria; supervision of statistical analysis and interpretation of results; thesis revision and approval
Dr Rozanne Kruger	Primary investigator of the EXPLORE study; application for ethics for the wider EXPLORE study; assistance with interpretation of methods and results
Sarah Philipsen	Assistance with data entry for the NZW-HDI derived food record
Zara Houston	Developed the NZWFFQ; SOP for NZWFFQ
Dr Rozanne Kruger and Adrianna Hepburn	Developed SOP for FR
Adrianna Hepburn, Zara Houston, and Sarah Philipsen, Andrea Fenner	Data entry for food records
Wendy O'Brien, Shakeela Jayasinghe, Dr Rozanne Kruger, Andrea Fenner, Jenna Schrijvers, Maria Casale, Adrianna Hepburn, Zara Houston, Sarah Philipsen, Richard Swift	Recruitment and screening of EXPLORE participants
Wendy O'Brien, Shakeela Jayasinghe, Dr Rozanne Kruger, Dr Pamela Von Hurst, Dr Kathryn Beck, Dr Cathryn Conlon, Richard Swift, Owen Mugridge, Maria Casale, Andrea Fenner, Jenna Schrijvers, Adrianna Hepburn, Sarah Philipsen, Richard Swift	Testing for EXPLORE participants that included: body composition analysis, blood pressure, taste perception, three dietary questionnaires (one of which was the NZWFFQ)
PC Tong	Assistance with equipment for data collection

Food Record, FR; NZWFFQ, New Zealand Women's Food Frequency Questionnaire; NZW-HDI, New Zealand Women's Healthy Diet Index; SOP, Standard Operating Procedure

2. Literature review

This review of the literature focuses on the development and validation of tools to assess diet quality in young women. Within this review, diet quality and associations with health and disease in women are explored. Next, dietary assessment methods used to measure dietary intake of individuals are critically analysed. The challenges faced with traditional methods are compared to alternative approaches, such as dietary patterns including the use of diet quality indices. A review of diet quality indices is conducted, followed by factors to consider when developing DQIs. Finally, methods used to validate a newly developed index are examined.

2.1 Young women and diet quality

Diet is one of the most modifiable factors in promoting optimal health and preventing disease. Modifiable dietary-related factors such as food intake (high salt, high saturated fat, low fruit and vegetable intake) and excess energy intake (related to high body mass index) are known to contribute to the risk of diabetes, heart disease, cancer and other conditions (Ministry of Health, 2012). Collectively, these risk factors account for 11.4% of health loss (i.e. a measure of healthy life lost due to early death, illness, or disability) in New Zealand (NZ) (Ministry of Health, 2012). As the burden of disease is steadily increasing, this greatly impacts healthcare costs. The cost of obesity alone, denoted as one of the major risk factors for non-communicable diseases, is estimated to be $460 million (Ministry of Health, 2009). Obesity in young adults has become more common, with a rise in obesity in young women aged 18-24 years, from 11.9% in the New Zealand Health Survey 2011/12 to 21.6% in 2014/15 (Ministry of Health, 2015a). It is widely recognised that poor dietary quality in young women is associated with weight gain (Kant, 2004). An increased consumption of nutrient poor, energy dense foods leads to an increased intake of sugar sweetened beverages and takeaways (Nour et al., 2014), and fewer women meeting the recommendations for fruit and vegetable intake (University of Otago and Ministry of Health, 2011b). There is also concern regarding micronutrient adequacy of females in New Zealand (NZ). It is well known that young premenopausal women are more at risk of iron deficiency because of menstruation, but also due to a lack of iron-rich foods in the diet (Heath et al., 2001). Beck et al (2013) observed associations between a low 'meat and vegetable' dietary pattern, or 'milk and yoghurt' dietary pattern, and an increased risk of suboptimal iron status. In New Zealand, iron deficiency is prevalent in 5-12% of females aged 15-50 years. Within this subset, inadequate calcium intake is more common, with 56-88% not meeting the recommended daily intake (University of Otago and Ministry of Health, 2011b). Calcium and iron are key nutrients for pregnant women and women planning pregnancy (Haines et al., 1999). Fetal programming highlights the importance healthy diet in young women. Poor nutrition in women of

childbearing age has the potential to create a cycle of adverse effects on the health of subsequent offspring (Reifsnider, 2003). Dietary influences during critical times in fetal development can lead to chronic disease later in life (Godfrey & Barker, 2001). Evidently, women need to maintain an optimal nutritional status before, during and between pregnancies, as an optimal diet quality preconception promotes favourable pregnancy outcomes (Mathews et al., 2008). In order to improve the nutritional status and diet quality of young women, thereby reducing the burden of disease, it is essential that the assessment of dietary intake is valid and accurate..

2.2 Dietary assessment

2.2.1 Levels of measuring food consumption

While nutritional epidemiology is still a relatively new science, the link between diet, health and disease has been known for centuries (Michels, 2003). As Hippocrates (460 – 377 BC), the father of medicine said: 'Let food be thy medicine, and medicine be thy food" (Hippocrates, 1955). The first population based studies on food consumption was in the 20th century. At the time only a few foods were correlated with disease outcomes (Orr, 1933; Stocks, 1958). Since then, more detailed dietary assessment methods have been developed.

Dietary assessment is of great significance to researchers, as it is crucial to investigate the relationship between diet, health**,** and disease (Buzzard, 1994). This is because useful information on food and nutrient intakes of both individuals and population groups can be obtained through dietary assessment methods. As a result, a lot of research has focused on improving the accuracy and reliability of existing methods, and creating new and efficient dietary assessment methods.

Dietary assessment methods are used at three different levels of food consumption – national, household, and an individual level (Gibson, 2005; Serra-Majem, 2001). Within each of these categories, different methods are used to obtain information on food consumption; such as frequency of intake, types of foods eaten, portion size of food, and dietary habits, which are expressed as nutrients, foods or dietary patterns (Biro et al., 2002; Thompson & Subar, 2008). National food consumption refers to food supply and production within a country (Thompson & Subar, 2008). The most commonly used method for assessing national food consumption is food balance sheets, but other methods such as total diet studies, market basket studies, universal product codes and electronic scanning devices are also used (Gibson, 2005). Estimates on a national basis are useful for nutrition policy as they provide information on food and nutrient availability of a country (Serra-Majem, 2001). At a household level, food consumption can determine the intake of a household, family, or organization. Dietary methods used include food accounts, household food

records, and household 24-hour recalls (Gibson, 2005). Demographic and socioeconomic information of the household is collected, allowing the data to be presented according to relevant characteristics such as income level, family size, and region (Gibson, 2005). Both national and household data is useful for monitoring population trends and geographical differences in nutritional status (Bingham, 1991).

Dietary assessment is frequently collected at the individual level to investigate associations between dietary intake, health and disease. Dietary data at the individual level can be used in both clinical and research settings (Grandjean, 2012). The following section focuses on dietary assessment methods suitable for individuals.

2.2.2 Assessment of dietary intake for individuals

A range of methods are available to measure dietary intake in individuals, but the four most common dietary assessment methods are presented in Table 2.2. These are based on varying characteristics that include: 1) retrospective or prospective – time period of information gathered; 2) short or long term – duration of assessment; and 3) qualitative or quantitative – type of information collected (Biro et al., 2002; Lee & Nieman, 2003). Dietary assessment methods measure dietary intake in the past or in the present time. Retrospective methods include the food frequency questionnaire (FFQ), diet history and 24-hour recall. These are reliant on an individual's memory to obtain dietary information (Thompson & Subar, 2008). The food record or diary is the only prospective method, in which participants record foods and beverages at the time of consumption (Willet, 1998). The length of dietary assessments can also vary from 24 hours (24-hour recall), 3-7 consecutive days (food record), to a month, several months, or a year (usually assessed by a FFQ and diet history) (Biro et al., 2002; Black, 2001). Ideally, seasonality and day-to-day variation should be considered (Biro et al., 2002; Jacobs Jr, 2012). In addition, the type of information gathered also differs. Quantitative measures of dietary intake include the 24-hour recall that uses household measures, and food records which use either household measures or food scales depending on whether the dietary information required is estimated or weighed (Thompson & Subar, 2008). These methods provide detailed information on actual nutrient intake (Biro et al., 2002). Qualitative methods such as the FFQ and diet history measure habitual intake of food items, food groups, and dietary patterns (Black, 2001). Advancements in dietary assessment methods has allowed the FFQ to become quantitative or semi-quantitative (Jacobs Jr, 2012; Lee & Nieman, 2003), whereby participants self-select their portion size or a standard portion size is provided (Willet, 1998). The diet history can be a combination of quantitative and qualitative data, depending on the information

needed from the interviewer (Biro et al., 2002; Thompson & Subar, 2008). With so many different ways to assess dietary intake, it can be difficult to choose a suitable method.

Selection of a method to assess dietary intake involves many considerations to ensure the method is appropriate for use. The choice depends primarily on the aims and objectives of the research (Grandjean, 2012). Other factors that can guide appropriate selection include: the type of dietary data collection needed; participant characteristics (such as age and literacy); nutrients, foods, or dietary behaviours of interest; the need for absolute or usual nutrient intake estimations, duration of the study, and availability of resources (such as materials, time and financial capabilities) (Biro et al., 2002; Grandjean, 2012). An in-depth review of the strengths and limitations of different methodologies also assists in determining which dietary method to use (Biro et al., 2002), as highlighted in Table 2.2.

The collection of dietary data from an individual is one of the most challenging aspects of nutritional epidemiology (Michels, 2003). It has proven to be difficult to accurately assess as it is fraught with uncertainties for several reasons. First of all under-reporting of energy intake is common. It has been identified that 77% of women are under-reporters (Rennie, Coward, & Jebb, 2007), and an investigation of the New Zealand Adult Nutrition Survey 2008/09 found the prevalence of low energy reporters to be greater in overweight and obese individuals (Gemming, Jiang, Swinburn, Utter, & Mhurchu, 2014). A common reason for this occurrence is social desirability bias, whereby individuals are selective in the omission of foods based on whether they are healthy or unhealthy (Hebert, Clemow, Pbert, Ockene, & Ockene, 1995). For example, failing to record the correct amount of chocolate consumed. Difficulty can also occur when estimating portion sizes consumed (for example using food records), and how often different foods are consumed (for example using FFQ's) (Gibson, 2005). Another challenge is that the human diet varies from day to day, which will ultimately alter nutrient intake (Black, 2001). To reduce the observed effects of dietary variation, 24-hour recalls have been conducted on random, non-consecutive days. In addition, increasing the timeframe of assessment for 24-hour recalls and food records has also been advised to reduce error (Gibson, 2005). Other factors that make assessment of dietary intake difficult include changes in season, systematic and random error, and limitations associated with the use of food composition tables (Biro et al., 2002; Gibson, 2005). Given that difficulty is faced with all methods of dietary assessment, there is no measure of diet will truly convey actual dietary intake (Grandjean, 2012; Nelson, 1997). Instead, these methods have the ability to represent usual diet. Weighed food records have been considered as the "gold" standard (Biro et al., 2002). However, even food records

have limitations such as under-reporting and high participant burden (Biro et al., 2002; Thompson & Subar, 2008).

A better understanding of the strengths and limitations of different dietary methods has allowed for new developments through methodological improvements, technological advancements, and validation studies (Biro et al., 2002). This has led to innovative approaches, such as blending instruments together to maximise the strengths of each method (Thompson & Subar, 2008), with the aim to increase accuracy and efficiency, and also minimise the cost (Jacobs Jr, 2012). For instance, a food record assisted 24-hour recall has been developed for children (Lytle et al., 1993). A record was kept by the children, which was then used as a memory prompt when a 24-hour recall was conducted. Other advancements include the use of web-based FFQs, audio questions with touch screen picture responses, telephone assisted approaches, use of digital images to record foods consumed, and electronic devices (e.g. mobile phones) to directly record dietary intake (Mann & Truswell, 2007; Thompson, Subar, Loria, Reedy, & Baranowski, 2010).

Although there are various methods to assess dietary intake, when investigating large study populations especially when dietary intake is not the main focus, dietary assessment methods are required to not only be valid, but efficient and easy to administer (Toft et al., 2007). To overcome this, simple tools that are user-friendly have been developed. Diet quality indices are one such method, and combine information on nutrients and foods into a single exposure. A summary measure or score is produced, allowing individuals and population groups to be characterised by the quality of their diet (Biltoft-Jensen et al., 2008).

Table 2.1 Overview of traditional dietary assessment methods for individuals

Dietary assessment method	Characteristics	Procedure	Strengths	Limitations
24-hour recall	Quantitative, prospective, and short term	-Interview that provides a recall on the type and quantities of foods and beverages consumed over the past 24 hours or previous day	-Efficient to administer (15 – 20 minutes) -Applicable to a wide range of ethnic population groups -No literacy requirement for participants -Low participant burden -Dietary pattern not altered	-Expensive to administer -Requires a skilled, trained interviewer for knowledge on food and nutrition -Relies on participant memory -Portion size difficult to estimate -Intake often underreported -Does not capture day-to-day variation
Food record	Quantitative, prospective, and short term	-Self-administered record kept of the foods and beverages consumed for one to seven days -Two types: Estimated food record uses household measures or food models to estimate portion size, and a weighed food record uses scales to measure foods consumed	-Provides information on foods consumed and eating patterns -Gathers additional information on portion size, preparation, and cooking methods -Reasonably accurate, if participants dietary pattern does not change -Use of visual aids helps participants accurately estimate dietary intake -Does not rely on participants memory -Open-ended	-Expensive to administer -Requires motivated, literate participants that require training -High participant burden and lower compliance -Participants fatigue decreases record reliability, particularly if more record days are kept -Intake often underreported -Eating pattern may be altered by recording process
Food frequency questionnaire	Qualitative, semi-quantitative or quantitative, retrospective, and long term	-Self-administered questionnaire consisting of a list of foods -Investigates the usual frequency of consumed food items over a specified period (mostly past month or year)	-Estimates usual dietary intake -Ranks individuals based on usual food or nutrient intake -Efficient data handling -Low administration cost -Does not influence participants eating pattern -Low respondent burden -Suitable for large population surveys	-Relies on participants memory -Recall period not quantifiably precise -Requires literate and numerate participants -Difficult cognitive task for participants -Intakes often misreported -Portion size difficult to estimate -Not open-ended

Dietary assessment method	Characteristics	Procedure	Strengths	Limitations
Diet history	Qualitative or quantitative, retrospective, long term	-Detailed interview to determine usual meal pattern over a specified period of time (usually past month, several months, or year)	-Estimates usual dietary intake -Information on whole diet gathered -Meal-based approach enhances participants memory -Low administration cost -Does not influence participants dietary pattern	-Requires a skilled, trained interviewer with knowledge on food and nutrition -Interviews may be un-standardised -Not useful for individuals that don't have a usual eating pattern -Recall period not quantifiably precise -Intake often misreported -Difficult cognitive task for participants

Note. Table adapted from Biro et al. (2002) and Thompson and Subar (2008)

2.3 Analysis of dietary data

Once dietary data has been collected, it is typically converted to nutrient or food data (traditional approach) and compared with reference standards. More recently, dietary data has been analysed using a dietary pattern approach.

2.3.1 The traditional approach - determination of nutrient and food intakes

Dietary data from food consumption is commonly converted into energy and nutrient intakes (Jacobs Jr, 2012). This can be calculated from food composition data, which provide information on the average nutrient content of foods consumed in a particular country. Food composition values are available within food composition tables or nutrient databases (Mann & Truswell, 2007). The completeness and precision of the database is vital, as ultimately this affects estimation of nutrient intake (Thompson & Subar, 2008). For this reason, the range of foods listed and availability of nutrient values for foods within the nutrient database should be investigated prior to use (Mann & Truswell, 2007).

2.3.2 Evaluation of nutrient and food intakes

To determine how healthy an individual's diet is, it needs to be compared to a reference standard (Mann & Truswell, 2007). In New Zealand and overseas, there are two main ways this can be achieved: nutrient reference values (NRVs) and food-based dietary guidelines (FBDG). Both are based on current nutritional knowledge and are country-specific. Firstly, energy and nutrient intakes can be compared to nutrient recommendations known as NRVs (National Health and Medical Research Council, 2006). These determine the amount of a particular macronutrient (e.g. fat) or micronutrient (e.g. calcium) required to maintain health at different life stages (National Health and Medical Research Council, 2006). However, as NRVs represent a wide range of nutrients, the general public may not understand how to assess their nutrient needs relative to NRVs.

Food-based dietary guidelines (FBDG) interpret nutrient recommendations into translatable dietary advice (European Food Safety Authority, 2010), allowing individuals to determine if their nutritional requirements are being met (Wardlaw, 2013). For FBDG to be effective, the food items need to be classified into food groups that are logical to the consumer (Löwik, Hulshof, & Brussaard, 1999). Hence, the guidelines are simple, food-based messages that are practical to follow. For example, if the population target for saturated fat is 10% of total energy, and the current intake is higher than this, messages are likely to be designed to reduce saturated fat intake, such as "trim the skin off meat or remove the skin off chicken".

Each country has their own unique FBDG due to differences in food availability, food access, culture, and socioeconomic influences (European Food Safety Authority, 2010). Nutritional objectives also differ between countries. For example, in developing countries, there is a focus on malnutrition and prevention of nutritional deficiencies; whereas in developed countries the objectives have shifted to the prevention of obesity and chronic diseases (Ministry of Health, 2015b; Wardlaw, 2013). In New Zealand, there are six population-specific Food and Nutrition Guidelines set by nutrition experts on behalf of the Ministry of Health (Ministry of Health, 2015b). Recently, there has been a transition to the Eating and Activity Guidelines Series. These guideline statements can be used by health professionals to provide nutrition education on healthy eating and physical activity (Ministry of Health, 2015b).

2.3.3 Limitations in the analysis of nutrient and food intake

Most studies examine the association between diet and disease based on individual foods or nutrients. This has enhanced our understanding of nutrient deficiencies (e.g. scurvy, rickets) and important dietary factors (e.g. vitamin C, calcium) that can prevent the occurrence of these conditions (Scrinis, 2013). Although insight gained has been invaluable, the reductionist approach has been criticised. The most popular and controversial example is the association between saturated fat (SF) and cardiovascular disease. In the 1950s saturated fat was shown to have detrimental effects on cardiovascular lipid profiles (Mozaffarian, Micha, & Wallace, 2010). Since then, evidence from randomised control trials behind this recommendation has been debated (Mozaffarian et al., 2010; Siri-Tarino, Sun, Hu, & Krauss, 2010).

The traditional analyses have inherent limitations for several reasons. Deconstructing food into nutrients may be counterproductive (Hu, 2002; Jacobs & Tapsell, 2013), as this does not take into account the fact people do not eat nutrients in isolation (Ocké, 2013; Waijers et al., 2007). Instead, whole foods are consumed, usually as part of a meal that consists of various dietary components (McNaughton et al., 2008). There is also a high level of inter-correlation between nutrients (e.g. calcium and phosphorus are often found in the same foods). On a biological level, interactions occur between nutrients and their bioavailability, absorption, and metabolism (Kant, 2004). To help illustrate this point, factors affecting iron absorption are often found within one meal. For example, breakfast cereal eaten with kiwifruit and milk contains a combination of nutrients (phytic acid, vitamin C, calcium) which may act synergistically or in opposition impacting on iron absorption (Beck et al., 2013; Hu, 2002; Moeller et al., 2007). Therefore, it is important that food synergy be considered due to the complex nature of the diet (Jacobs, Gross, & Tapsell, 2009). This concept implies that nutrients within the food matrix work together to exert effects on health (Jacobs &

Tapsell, 2013). Another example of nutrient correlation is shown in dietary intervention studies that attempt to modify the intake of one nutrient, which in turn alters intake of other nutrients (Lissner et al., 2006). Considering the limited variability of energy intake in terms of macronutrient distribution (Michels & Schulze, 2005), a low fat intake ultimately leads to a higher intake of carbohydrates (Scrinis, 2013). Other reasons for considering the whole diet are the possibility that the effects of a single nutrient may not be detected, statistically significant associations may occur by chance when analysing multiple nutrients, and finally detecting associations with single nutrients may be confounded by dietary patterns (Hu, 2002; Moeller et al., 2007; Ocké, 2013).

2.4 An alternative approach - dietary pattern analysis

Dietary patterns offer an alternative approach to explore the relationship between diet, health, and disease. As opposed to traditional dietary assessment methods that typically study the effect of single nutrients and foods, dietary pattern analysis overcomes the inherent problems associated with analysis of individual foods or nutrients (Hu, 2002). Particular combinations of foods and nutrients as described by dietary patterns are a closer parallel to how people eat (Michels & Schulze, 2005). Dietary patterns consider the whole diet, and are shaped by individual preferences, income, culture, and the environment (Ocké, 2013). This has allowed healthy and unhealthy dietary patterns to be identified (Waijers & Feskens, 2005), which can help with disease prevention or treatment (Hu, 2002). The patterns can then be used to examine relationships with nutrient intakes, risk factors, and biomarkers (Moeller et al., 2007). A prime example is The Dietary Approaches to Stop Hypertension (DASH) trial, which found that a diet abundant in fruit, vegetables, and whole grains with a low amount of fat and meat reduced blood pressure (Sacks et al., 2001). In addition, as dietary patterns are emphasised in dietary guidelines, they provide a practical way to evaluate the health effects of adherence to dietary guidelines by individuals (Huijbregts et al., 1997). Empirical and theoretical approaches can be used to derive dietary patterns. These are summarised in Table 2.2.

2.4.1 Empirically derived dietary patterns

Dietary patterns can be derived through the use of empirical methods. An *a-posteriori* approach is used, whereby patterns are not determined in advance, but are instead data-driven (Michels & Schulze, 2005). Dietary information from food consumption data is typically analysed using two common empirical techniques known as factor analysis and cluster analysis (Michels & Schulze, 2005). Factor analysis is a term that describes both principal component analysis and common factor analysis (Hu, 2002). Principal component analysis is commonly used to derive dietary patterns and

uses dietary information obtained from 24-hour recalls, food records, and FFQs (Hu, 2002; Moeller et al., 2007). Food items or food groups from available data found to be correlated are grouped together as dietary components, and are distinct from components that are not correlated (Michels & Schulze, 2005; Waijers & Feskens, 2005). Therefore, this approach reduces data into patterns based upon inter-correlations between dietary components (Newby & Tucker, 2004). In contrast, cluster analysis reduces data into patterns based upon individual differences in mean intake (Waijers & Feskens, 2005). Unlike factor analysis that aggregates food items/groups (Michels & Schulze, 2005), individuals with similar diets are placed into homogenous groups (clusters) (Waijers & Feskens, 2005). Statistical methods derive a summary score for each pattern which can be used for establishing associations with health outcomes (Hu, 2002).

2.4.2 Theoretically derived dietary patterns

2.4.2.1 Diet quality indices – a new dietary assessment method

Diet quality indices or scores are another approach in assessing and identifying dietary patterns. Dubois, Girar & Bergeron (2000) suggested that while it is "easy to assess diet in terms of consumption of particular food items, developing a single indicator for the measurement of overall diet quality is a more complex task". In light of this, DQIs allow diet quality to be measured as a single exposure. Utilising an *a priori* approach, they are based on current knowledge of what constitutes a healthy diet primarily using national dietary guidelines and recommendations, or a diet known to be beneficial (e.g. the Mediterranean diet) (Kant, 1996; Wong et al., 2013). DQIs are generally classified depending on the index constructs: 1) indices based on nutrients only, 2) indices based on specific foods or food groups, and 3) indices that combine both nutrients and foods (Kant, 1996). Hence, the index is made up of a combination of dietary components such as nutrients, foods, and food groups (Wong et al., 2013). Other aspects of diet quality such as dietary variety have also been included in some indices (Drewnowski, Renderson, Driscoll, & Rolls, 1997). Dietary components included in the DQI are then quantified, and a summary score is produced as a measure of overall diet quality (Kourlaba & Panagiotakos, 2009a; Waijers & Feskens, 2005).

2.4.2.2 Purpose of diet quality indices

As with any dietary assessment method, the purpose of the index must be decided prior to development (Thompson, Subar, Coulston, & Boushey, 2008). Emphasis has been placed on ensuring the purpose of the DQI is clear (Wirfält, Drake, & Wallström, 2013). The intended use of indices varies, from adherence to national dietary guidelines or a healthy diet (Mediterranean diet or Dietary Approaches to Stop Hypertension diet) (Fransen & Ocke, 2008), to predicting risk of health

outcomes. The risk of undesirable health outcomes can be measured using biomarkers (e.g. carotenoids, vitamin C, and cholesterol) (Huijbregts et al., 1997; Weinstein, Vogt, & Gerrior, 2004), disease risk (e.g. cardiovascular disease and some types of cancer), and all-cause mortality (McCullough et al., 2000; Waijers et al., 2007). A number of DQIs even set out to achieve more than one purpose. These indices aim to predict the risk of health outcomes and adherence with dietary guidelines (Harnack, Nicodemus, Jacobs, & Folsom, 2002; Kennedy et al., 1995; Kourlaba & Panagiotakos, 2009a).

Moreover, dietary indices are tailored to the population groups to meet nutritional requirements of different life stages (Woodruff & Hanning, 2010). Diet quality indices have been developed for use in population groups such as children and adolescents, pregnant women and the elderly (Alkerwi, 2014; Fransen & Ocke, 2008). It is also important to realise that differences in food availability, food intake, and culture will influence the dietary patterns of a country which will ultimately affect the composition of the index (Collins et al., 2015; Wirfält et al., 2013). Likewise, national dietary guidelines reflect current nutritional issues that need to be addressed in a particular country (European Food Safety Authority, 2010; Wardlaw, 2013). To reflect such characteristics, DQI are region or country specific. To address all of the above, existing DQIs vary in the type, number and emphasis of components according to the purpose, population group, and country of the research (Alkerwi, 2014).

2.4.2.3 Application of diet quality indices

The use of diet quality indices is predominantly within the public health sector. Unlike other dietary assessment methods used, the DQI is simple to understand and does not require a high degree of background knowledge in nutrition to be interpreted. This means it can be used at all levels of public health - from researchers to policy makers, and clinical practitioners (Alkerwi, 2014). Indices can monitor the health status of a population (Alkerwi, 2014; Kennedy et al., 1995). When repeated over time, DQIs can track changes in food consumption patterns within a population, and compare diet quality within and between different populations (Mazzocchi, Brasili, & Sandri, 2008; Ocké, 2013). This information may prove useful for policy makers to evaluate the need for nutrition interventions (Ocké, 2013; Wirt & Collins, 2009). Another key point is that because DQIs can assess the adherence to dietary guidelines (Alkerwi, 2014), this provides a practical way to determine the effectiveness of national dietary guidelines in relation to risk of disease (Ocké, 2013). Therefore, dietary indices can assist in the development of strategies for disease prevention (Alkerwi, 2014; McNaughton et al., 2008). To date most indices have been used for epidemiologic purposes, although clinical application has been encouraged (Wirt & Collins, 2009). As DQIs are easily

interpreted by the public (Waijers & Feskens, 2005), they can serve as a useful tool for nutrition education (Kennedy et al., 1995). Hence, indices can be used as an educational resource by dietitians and other health professionals (Alkerwi, 2014). Additionally, dietary indices can be useful in developing countries that do not have the resources to implement accurate nutritional screening and monitoring. Indices have been proposed as a summary measure for screening the population (Alkerwi, 2014), and as a proxy tool to examine food insecurity (Ocké, 2013). The remaining review of the literature focuses on the use, development, and validation of DQIs.

Table 2.2 Types of dietary pattern analysis methods and their relative strengths and limitations

Dietary pattern method	Characteristics	Advantages	Limitations
Factor analysis	-Reduces food items or food groups into patterns based on inter correlations between components	-Use of continuous components increases statistical power -Participants receive a score for all dietary patterns -Does not depend on how the author defines a healthful pattern	-Derived from empirical data therefore may not reflect optimal dietary patterns -Does not identify between individuals -Identifies patterns that do not reflect dietary guidelines -Requires in-depth statistical analysis -Difficult to analyse and interpret -High degree of subjectivity (grouping of food items, treatment of input components, analytic decisions, selecting a pattern solution)
Cluster analysis	-Reduces data into patterns based upon individual differences in mean intake -Individuals with similar diets are placed into homogenous groups	-Provides a categorical descriptions of what subgroups of the population consume -Does not depend on how the author defines a healthful pattern	- Grouping individuals into clusters reduces statistical power -Derived from empirical data therefore may not reflect optimal dietary patterns -Identifies patterns that do not reflect dietary guidelines -Requires in-depth statistical analysis -Difficult to analyse and interpret -High degree of subjectivity (grouping of food items, treatment of input components, analytic decisions, selecting a pattern solution)
Diet quality index/score	-Assesses the adherence of individuals to dietary guidelines or specific diet	-Simple to administer -Easy to interpret -Inexpensive to administer -Reproducible and comparable with other populations	-Low research and respondent burden -Attributes are selected by the investigator -Degree of subjectivity (interpretation of guidelines, construction of the index) -Dichotomous components do not consider full range of amounts of foods consumed -Dependent on selected dietary guidelines

Note. Adapted from Moeller et al. (2007)

2.5 Previous research on diet quality indices developed based on dietary guidelines

It is recommended to utilise other diet quality indices (DQIs) available to assist in the development of a DQI. A review was conducted that focused on DQIs meeting the following criteria: (i) used in an adult population (ii) included women; (iii) based on national dietary guidelines; (iv) and indices based on the Mediterranean diet excluded. The rationale of specific selection criteria was to ensure the purpose of research, and population group of interest were considered.

A wide range of diet quality indices have been developed, with over 25 distinct DQIs used in an adult population (Wirt & Collins, 2009). The most referenced, revised and modified diet quality indices are the Diet Quality Index (DQI), the Healthy Eating Index (HEI), the Healthy Diet Indicator (HDI) and the Mediterranean Diet Score (MDS) (Waijers et al., 2007). These indices have undergone several modifications and adaptations over the years. The HDI was used a large cohort of men for the study, and the MDS based on the Mediterranean diet, therefore these indices and their derivatives were not covered in this review. Table 2.3 shows previous studies using DQIs developed overseas, in Australia and New Zealand that fit the above criteria. Based on the findings from the various DQIs available in different countries, there is a general consensus that higher DQI scores, which reflect greater adherence to dietary guidelines, correlate with improved nutrient adequacy (Fogli-Cawley et al., 2006; Patterson et al., 1994; Zarrin, Ibiebele, & Marks, 2013). Indices of diet quality have also been related to health outcomes such as biomarkers (Toft et al., 2007), cancer (Harnack et al., 2002), all-cause mortality (Kant, Schatzkin, Graubard, & Schairer, 2000).

2.5.1 Original diet quality indices – an overview

In 1994, the Diet Quality Index was the first index constructed to measure overall diet quality (Patterson et al., 1994). Once the new dietary guidelines were introduced, the Diet Quality Index Revised (DQI-R) was developed (Haines et al., 1999). The revision reflected current dietary guidelines and incorporated measures of dietary variety and moderation (Kourlaba & Panagiotakos, 2009a). Although the DQI-R originally used men as the sample population, another study evaluated the DQI-R using women (Fung et al., 2005). Another tool based on the original DQI, the Diet Quality Index International (DQI-I), was developed to allow international comparison for global monitoring of diet quality across countries (Kim, Haines, Siega-Riz, & Popkin, 2003). The DQI-I compared diet quality of populations in China and the United States using two separate datasets, and was successful in evaluating aspects of a healthy diet in both countries. Another key index, the Healthy Eating Index (HEI), was based on the 1995 Dietary Guidelines for Americans (Kennedy et al., 1995). The original HEI has been superseded by the HEI-2005 and HEI-2010 (Alkerwi, 2014). After the 2005 Dietary

Guidelines for Americans were released, the HEI was revised to address changes in the guidelines such as an increased emphasis on whole grains, different types of vegetables, certain types of fat and discretionary kilojoules (Guenther, Reedy, & Krebs-Smith, 2008). Further changes were made to the HEI once the 2010 Dietary Guidelines and United States Department of Agriculture (USDA) Food Patterns were revised. Briefly, the HEI-2010 modified components, including the addition of seafood and highlighting the reduction of refined grains (Guenther et al., 2013). Huijbregts et al. (1997), developed the Healthy Diet Indicator that is based on the dietary recommendations for disease prevention set by the World Health Organisation. Given that the purpose of the index has only been assessed in a male population, this index will not be further discussed in this review.

2.5.2 Diet quality indices developed overseas

Although the majority of indices have been created with reference to United States (US) dietary guidelines, there are an increasing number of indices developed internationally in different geographic locations (Marshall, Burrows, & Collins, 2014). This includes many parts of Europe such as Denmark and Norway (Biltoft-Jensen et al., 2008; Löwik et al., 1999), China (Stookey, Wang, Ge, Lin, & Popkin, 2000), Canada (Shatenstein, Nadon, Godin, & Ferland, 2005), and Australia (Australian Institute of Health and Welfare, 2007; Collins et al., 2015). Some have tailored original DQIs to suit their national dietary guidelines (Collins et al., 2015; Haines et al., 1999; Shatenstein et al., 2005), while others have developed an entirely new tool to make the index country-specific (Bazelmans et al., 2006; McNaughton et al., 2008). For example, the Healthy Eating Index based on US guidelines was adapted to the Canadian dietary guidelines to reflect the dietary patterns of this area (Woodruff & Hanning, 2010). Given that the US Food Pyramid and Canada's Food Guide are designed to meet similar nutrient needs, the HEI was relatively easy to adapt for Canada (Garriguet, 2009). On the other hand, the Diet Quality Score was developed based solely on Danish Dietary Guidelines, and therefore was completely unique to the Danish diet (Toft et al., 2007).

2.5.3 Diet quality indices developed in Australia

In the Australian context, several indices have been developed based on the same dietary guidelines for Australian adults, and on the same population group (aged >19 years). These include the Australian Healthy Eating Index (Aust-HEI) (Australian Institute of Health and Welfare, 2007); Dietary Guidelines Index (DGI) (McNaughton et al., 2008); Australian Recommended Food Score (ARFS) (Collins et al., 2015); the Aussie-DQI (Zarrin et al., 2013); and the Healthy Eating Index for Australiana adults 2013 (HEIFA-2103) (Roy et al., 2015). These indices were developed for different purposes: the Aust-HEI focussed more on diet quality in relation to chronic disease risk (Australian Institute of Health and Welfare, 2007); the DGI assessed adherence to dietary guidelines (McNaughton et al.,

2008); the ARFS aimed to examine the validity and reproducibility of the index against an FFQ (Collins et al., 2015), the Aussie-DQI linked food and nutrients related to health outcomes alongside critically evaluating validation measures (Zarrin et al., 2013) and the HEIFA-2013 was based on updated Dietary Guidelines for Australians 2013 and validated against a weighed food record. Although these indices are based on the same dietary guidelines, the purpose of the DQIs differs. As a result, differences between these indices lie in the choice of index components, scoring systems, and types of dietary data used. Examples can be seen in Table 2.3.

2.5.4 Diet quality indices developed in New Zealand

In New Zealand there is currently no method to assess diet quality of adults, more specifically for young women. The only index developed so far is the New Zealand Diet Quality Index for Adolescents (NZDQI-A), which was developed to examine diet quality of 14 to 18 year olds (Wong et al., 2013). However, because of differences in nutrient recommendations, food choices, and dietary intake between adolescents and adults (Wong et al., 2013), the application of the NZDQI-A is not suitable for use in an adult population.

Table 2.3 Overview of diet quality indices developed based on dietary guidelines or recommendations

Author, year, country	Index	Sample size and participant characteristics	Dietary guidelines used	Data collection method	Number of components and scoring system	Validation method	Main findings
			Overseas				
(Bazelmans et al., 2006), Belgium	Healthy Food and Nutrient Index (HFNI)	11193 Belgian adults, 25 – 74 y	National Nutrition Council Belgium	1-day food record	9 components, total score from 0-9	All-cause mortality risk	Higher HFNI scores related to reduced risk of mortality in men
(Biltoft-Jensen et al., 2008), Denmark	Simple Diet Quality Index (SDQI)	3151 adults, 18-35 y	Nordic Nutrition Recommendations 2004 and Danish Dietary Guidelines 2005	7-day food record	2 components, total score from 0-200	Nutrient adequacy	Higher compliance to guidelines associated with better nutrient profile
(Fogli-Cawley et al., 2006), USA	Dietary Guidelines for Americans Index (DGAI)	3323 US adults, mean age 54 y	Dietary Guidelines for Americans 2005	FFQ	9 components, total score from 0-9	Nutrient adequacy	Higher DGAI scores positively associated with improved intakes of carbohydrate, protein, fibre, vitamins and minerals, and negatively associated with fat and cholesterol intakes
(Guenther, Reedy, & Krebs-Smith, 2008), USA	Healthy Eating Index – 2005 (HEI-2005)	8650 US subjects, >2 y	Dietary Guidelines for Americans 2005	24 hour recall and food record	10 components, total score from 0-100	Nutrient adequacy	Components scores of the HEI-2005 independent of energy intakes

Author, year, country	Index	Sample size and participant characteristics	Dietary guidelines used	Data collection method	Number of components and scoring system	Validation method	Main findings
			Overseas				
(Guenther et al., 2014), USA	Healthy Eating Index – 2010 (HEI-2010)	8262 US subjects, >2 y	Dietary Guidelines for Americans 2005 and USDA Food Patterns	Two 24-hour recalls	10 components, total score from 0-100	Nutrient adequacy	Low correlation observed between energy intake and HEI-2010 total and component scores
(Harnack et al., 2002), USA	Dietary Guidelines Index (DGI-a)	34708 US postmenopausal women, 55 – 69 y	Dietary Guidelines for Americans 2005	FFQ	9 components, total score from 0-18	Risk of cancer	Cancer incidence significantly lower with higher DGI scores
(Kant et al., 2000), USA	Recommended Food Score (RFS)	42254 US women, mean age 61 y	Consumption of recommended foods in current US dietary guidance	FFQ	23 components, total score from 0-23	All-cause mortality	RFS inversely associated with reduced all-cause mortality
(Kennedy et al., 1995), USA	Healthy Eating Index (HEI)	7443 US subjects, >2 y	US Food Guide Pyramid and Dietary Guidelines for Americans	24 hour recall	10 components, total score from 0-100	Nutrient adequacy	HEI positively correlated with intake of vitamins and minerals
(Kim et al., 2003), China	Diet Quality Index International (DQI-I)	8269 Chinese adults 9218 US adults, ≥20 years old	World Health Organisation food based dietary guidelines, Food Pyramid Guide	Three consecutive 24 hour recalls Two 24 hour recalls	17 components, total score from 0-100	Nutrient adequacy	Many nutrients associated with the index. DQI-I effective in cross-comparisons between countries

Author, year, country	Index	Sample size and participant characteristics	Dietary guidelines used	Data collection method	Number of components and scoring system	Validation method	Main findings
			Overseas				
(Lee et al., 2008), Taiwan	Overall Dietary Index Revised (ODI-R)	46238 Taiwanese adults, 18 – 84 y	Taiwanese Dietary Recommendations	FFQ	9 components, total score from 0-100	Nutrient adequacy	Correlations for fibre and micronutrients improved with the higher ODI-R scores
(Löwik et al., 1999), Netherlands	Diet Quality Index Alternative (DQI-a)	9218 US adults and 1493 Dutch adult women, 18 – 60 y	Dutch Dietary Guidelines	Two 24 hour recalls and two food records	5 components, total score from 0-25	Nutrient adequacy	DQI-a associated with improved intake of nutrients
(McCullough et al., 2000)	Alternate Healthy Eating Index (A-HEI)	62272 US women, 30 – 55 y	Dietary Guidelines for Americans 1995	2-day food record and FFQ	9 components, total score from 2.5-87.5	Risk of disease	No or low correlation with risk of chronic disease
(Osler et al., 2001), Denmark	Healthy Food Index (HFI)	7316 Danish adults, 30 – 60 y	Current recommendations for a healthy diet and previous indices	FFQ	4 components, total score from 0-4	Risk of CHD	No association between HFI and coronary heart disease risk
(Patterson et al., 1994), USA	Diet Quality Index (DQI)	5484 US adults, >21 y	1989 US recommendations from Diet and Health	24-hour recall and 2-day record	8 components, total score from 0-16	Nutrient adequacy	Higher DQI scores positively associated with vitamin and mineral intakes and inversely associated with fat intake

Author, year, country	Index	Sample size and participant characteristics	Dietary guidelines used	Data collection method	Number of components and scoring system	Validation method	Main findings
			Overseas				
(Stookey et al., 2000), China	Chinese Diet Quality Index (DQI-C)	7450 adults, 20 – 59 y	World reference values, Chinese Recommended Daily Allowances, and Food Guide Pagoda	Three consecutive 24-hour recalls	11 components, score from -12 - 0	Nutrient adequacy	DQI-C significantly correlated with food and nutrient intakes, and sensitive to over- and under nutrition
(Shatenstein et al., 2005), Canada	Canadian Healthy Eating Index (Canadian-HEI)	248 Canadian adults, 18 – 82 y	1993 Canada's Good Guide to Healthy Eating and 1990 Canadian Nutrient Recommendations	FFQ	9 components, total score from 0 - 100	Nutrient adequacy	Canadian HEI showed positive correlations with fibre, vitamin C and folate
(Toft et al., 2007), Denmark	Diet Quality Score (DQS)	6542 adult women and men, 30-60 y	Danish Dietary Guidelines	FFQ	4 components, total score from 0 -12	Nutrient adequacy, independent reference method	DQS associated with lower intake of saturated fat, and higher intakes of fibre, vitamins and minerals, fruit, vegetables, fish, and wholegrain foods. DQS negatively associated with total cholesterol, triglycerides, and LDL cholesterol, and homocysteine

Author, year, country	Index	Sample size and participant characteristics	Dietary guidelines used	Data collection method	Number of components and scoring system	Validation method	Main findings
Australia							
(Australian Institute of Health and Welfare, 2007), Australia	Australian Healthy Eating Index (Aust-HEI)	3559 Australian adults, ≥19 y	Dietary Guidelines For Australian Adults and the Australian Guide to Healthy Eating	FFQ and SDQ	7 components, total score from 0-60	Nutrient adequacy	Aust-HEI correlated negatively with total fat and saturated fat, and positively correlated with fibre, fruit, and vegetable intake
(Collins et al., 2015), Australia	Australian Recommended Food Score (ARFS)	Australian adults, ≥19 y	Dietary Guidelines For Australian Adults and the Australian Guide to Healthy Eating	AES FFQ	8 components, total score from 0-73	Nutrient adequacy	ARFS correlated with vitamin and mineral intakes
(McNaughton et al., 2008), Australia	Dietary Guideline Index (DGI-b)	8220 Australian adults, ≥19 y	Dietary Guidelines For Australian Adults and the Australian Guide to Healthy Eating	FFQ and FHQ	15 components, total score from 0-150	Nutrient adequacy	Higher DGI scores associated with lower intakes of energy, total fat, and SF, and higher intakes of fibre, vitamin C, folate, calcium, and iron
(Roy, R., Hebden, L., Rangan, A., & Allman-Farinelli, M., 2015), Australia	Healthy Eating Index for Australian Adults (HEIFA-2013)	100 Australian adults, 18 – 34 y	Healthy Eating Index for Australian Adults	FFQ	11 components, total score from 0-100	Nutrient adequacy	Higher HEIFA-2013 scores associated with lower intake of SF and sodium, and higher intakes of vitamins and minerals

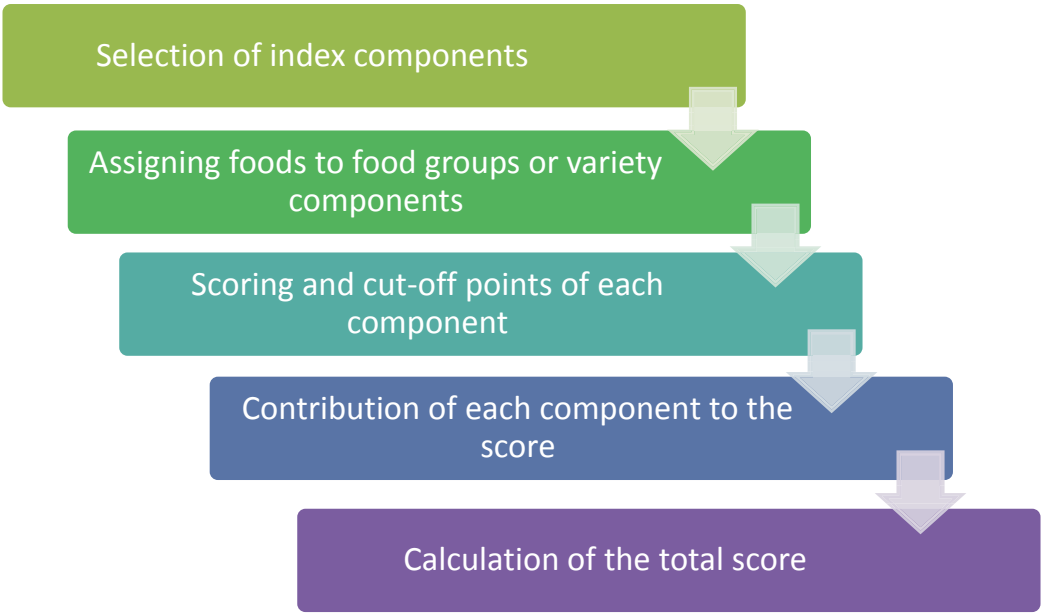
Author, year, country	Index	Sample size and participant characteristics	Dietary guidelines used	Data collection method	Number of components and scoring system	Validation method	Main findings
Australia							
(Zarrin et al., 2013), Australia	Aussie-DQI	Australian adults, ≥19 y	Dietary Guidelines For Australian Adults and Australia National Health Priority Areas	24-hour recall	14 components, total score from 0-120	Nutrient adequacy, risk of cancer and all-cause mortality	Higher Aussie-DQI scores associated with higher intakes of fruit, vegetables, cereals, iron, folate, vitamin C, and variety, and lower intakes of meat, processed meat, alcohol, total SF, and energy in both men and women. Aussie-DQI scores were inversely associated with cancer mortality among men
New Zealand							
(Wong et al., 2013), New Zealand	New Zealand Diet Quality Index for Adolescents (NZDQI-A)	41 New Zealand adolescents, 14 – 18 y	New Zealand Food and Nutrition Guidelines for Healthy Adolescents	NZAFFQ	4 components, total score from 0-100	Nutrient adequacy, independent reference method	Higher NZDQI-A associated with lower intakes of total fat and SFA, and higher intakes of iron

AHEI, Alternate Healthy Eating Index; AES FFQ, Australian Eating Survey; Aussie-DQI, Australian Diet Quality Index; Aust-HEI, Australian Healthy Eating Index; ARFS, Australian Recommended Food Score; Food Frequency Questionnaire; Canadian-HEI, Canadian Healthy Eating Index; CHD, Coronary Heart Disease; CVD, Cardiovascular Disease; DGI-a, Dietary Guidelines Index; DGI-b, Dietary Guideline Index; DGAI, Dietary Guidelines for Americans Index; DQI-a, Diet Quality Index Alternative; DQI, Diet Quality Index; DQI-C, Chinese Diet Quality Index; DQI-I, Diet Quality Index International; DQS, Diet Quality Score; FFQ, Food Frequency Questionnaire; FHQ, Food Habits Questionnaire; HEI, Healthy Eating Index; HEI-2005, Healthy Eating Index – 2005; HEIFA-2013, Healthy Eating Index for Australian Adults; HFI, Healthy Food Index; HFNI, Healthy Food and Nutrient Index; LDL, Low-Density Lipoproteins; ODI-R, Overall Dietary Index Revised; NZDQI-A, New Zealand Diet Quality Index for Adolescents; NZAFFQ, New Zealand Adolescent Food Frequency Questionnaire; RFS, Recommended Food Score; SF, Saturated Fat; SDQ, Short Dietary Questions; Simple Diet Quality Index; USDA, United States Department of Agriculture

2.6 Development of a diet quality index

In order to develop a diet quality index (DQI) based on dietary guidelines, several considerations need to be made in relation to the construction of the tool. As outlined in Figure 2.1, composing dietary indices involve many choices, such as the type and number of components, assigning respective cut off values to define optimal diet, and scoring criteria. For this reason, development of a DQI requires extensive review of the literature prior to investigator decisions being made. It is also imperative the purpose of the index be considered throughout the development process.

Figure 2.1 Stages involved in the development of a DQI



2.6.1 Selection of index components

Diet quality indices can range from simple tools to complex measures, as indices differ in the number of components included. For example, the Simple Diet Quality Indicator (sbqi) quickly assessed diet quality based on two components – saturated fat and dietary fibre (Biltoft-Jensen et al., 2008), whereas the Dietary Guidelines Index for Americans was a comprehensive index that included 20 food and nutrient components (Fogli-Cawley et al., 2006). It should be noted that depending on the type of components (e.g. total fat and saturated fat), complex indexes with too many components may be highly correlated with one another (Alkerwi, 2014; Biltoft-Jensen et al., 2008). Inter-correlation between components should be determined prior to use, as an increasing number of

index components increases diagnostic accuracy, but only if components have low correlation (Kourlaba & Panagiotakos, 2009b).

When developing a new index, researchers use different approaches to determine the type of components to be included. These approaches include prior knowledge (Huot et al., 2004, Kennedy et al., 1995), literature searches (Australian Institute of Health and Welfare, 2007) local nutritional priorities (Biltoft-Jensen et al., 2008) and availability of data for applied components (Shatenstein et al., 2005).

A common approach is to adopt components from previously developed DQIs. These provide a useful guide in the development process. As previously mentioned, the components of the four original indices – the Diet Quality Index (Patterson et al., 1994), the Healthy Eating Index (Kennedy et al., 1995), the Healthy Diet Indicator (Huijbregts et al., 1997), and the Mediterranean Diet Score (Trichopoulou et al., 1995) have been widely adopted to other indices.

DQIs based on dietary guidelines generally select components to reflect aspects of diet quality highlighted in the guidelines (Stookey et al., 2000). Indices based on dietary guidelines tend to be selective of their chosen components (Kennedy et al., 1995), as the inclusion of components depends on whether they are within the guidelines utilised (Román-Vinas et al., 2009).

2.6.2 Types of components used

In general, DQIs include nutrients, foods, or dietary behaviours as index components. These components are deemed either beneficial or unfavourable to health (Waijers et al., 2007). Some indices contain nutrients only (Biltoft-Jensen et al., 2008), foods only (Collins et al., 2015), while others combine foods and nutrients (Bazelmans et al., 2006; Patterson et al., 1994), or foods, food groups and dietary behaviours (McNaughton et al., 2008).

2.6.2.1 Index components - nutrients

- Macronutrients

When nutrients are incorporated into an index, they tend to include either macronutrients, micronutrients, or both. The unit in which intakes are expressed differs between indices and between nutrients. Macronutrients are usually expressed in terms of percentage contribution to energy intake, whereas micronutrients are determined by nutrient reference values (Waijers & Feskens, 2005). For example in the HEI, a moderate consumption of fat was considered <30% kcal from fat, and the ideal amount of sodium was less than 2400 mg (Kennedy et al., 1995). Nutrients found in various diet quality indices are listed in Table 2.4. With respect to fat, five different types of

fat have been used in the literature, including total fat, saturated fat, trans fat, mono-unsaturated and polyunsaturated fat. Total fat is a macronutrient that has been used in several indices such as the DQI and its revisions and adaptations, Healthy Eating Index (HEI), Canadian Healthy Eating Index (Canadian-HEI) Diet Quality Score (DQS), Dietary Guidelines Adherence Index (DGAI), Healthy Food and Nutrient Index (HFNI), and Dietary Guidelines Index (DGI-a). This is because excess fat consumption is related to obesity and many other health conditions (University of Otago and Ministry of Health, 2011a). Saturated fat (SFA) is the most commonly used nutrient as a component used in DQIs. It is often simultaneously incorporated into an index with total fat and/or cholesterol, as dietary recommendations advise limiting fat consumption, particularly saturated fat due to its role in coronary heart disease (Astrup et al., 2011; Waijers et al., 2007), SFA has been included in many of the indices developed (Biltoft-Jensen et al., 2008; Kim et al., 2003; Patterson et al., 1994). Likewise, due to the adverse effects of trans fatty acids (Hu, Manson, & Willett, 2001), trans fatty acids have been included in the Alternative Healthy Eating Index (AHEI) and DGAI. On the other hand, due to their positive associations with coronary heart disease (CHD), polyunsaturated fat and monounsaturated have been used in the Healthy Eating Index 2010 (HEI-2010) and the HFNI (Bazelmans et al., 2006; Waijers et al., 2007). Fat has also been viewed in regards to the ratio of mono- or poly unsaturated fat to SFA, although this was only done in the AHEI (McCullough et al., 2000). This can create unnecessary complications, for example the time taken to calculate the ratio. To make the index as simple as possible, it has been suggested that fatty acid ratios are avoided (Waijers et al., 2007). Carbohydrates are sometimes included in indices. For example, as starchy foods such as rice are staple foods in China, total carbohydrates was considered to be a reasonable indicator for the Chinese Diet Quality Index (Stookey et al., 2000). Segmenting carbohydrates into dietary fibre, mono- and disaccharides have also been constructed as components (Waijers & Feskens, 2005). A common component used in DQIs is sugary food (e.g. sugar-sweetened beverages and chocolate, due the link between sugar and obesity) (Parnell et al., 2008). A diet rich in fibre has a number of benefits to health including prevention of CHD and cancer, therefore has been included several indices (Fogli-Cawley et al., 2006; Kim et al., 2003). Protein was initially used as a component in the HEI and DQI, however, protein is rarely used in newly developed indices (Waijers et al., 2007). This may be because meat and meat products (that contain protein) are more commonly used as a food group.

- Micronutrients

Micronutrients such as sodium, calcium, iron, vitamin C and beta-carotene have also been included in some indices. About 40% of indices complying with dietary guidelines used sodium as a component to assess salt intake (Fogli-Cawley et al., 2006; Guenther et al., 2014; Kennedy et al., 1995; Lee et al., 2008; Patterson et al., 1994; Shatenstein et al., 2005; Stookey et al., 2000; Zarrin et al., 2013), because evidence suggests that restricting salt intake reduces blood pressure (Sacks et al., 2001). Salt or sodium intake needs to be measured carefully, since the proportion of salt used during or after cooking varies. In the Chinese Diet Quality Index, salt intake was estimated by calculating the salt stock, purchased salt and food preparation waste prior to data collection (Stookey et al., 2000). Calcium has also been used in the DQI and its derivatives, but is often reflected through the use of food groups (e.g. milk and milk products). Likewise, iron is often replaced as an index component with the food group meat and meat products.

Table 2.4 Nutrients included as components in previous diet quality indices

Name of index	Energy	Total fat	Saturated fat	Polyunsaturated fat	Monounsaturated fat	MUFA/SFA:PUFA	Trans fatty acids	Cholesterol	Protein	Carbohydrates	Mono-saccharides/ disaccharides	Dietary fibre	Alcohol	Sodium	Calcium	Iron	Vitamin C	Beta-carotene
DQI		✓	✓					✓	✓					✓	✓			
DQI-R		✓	✓					✓							✓	✓		
DQI-C	✓	✓	✓						✓	✓			✓	✓	✓			
DQI-I		✓	✓					✓				✓		✓	✓	✓	✓	
DQI-a		✓	✓					✓		✓	✓							
SDQI			✓									✓						
HEI		✓	✓					✓	✓					✓				
HEI-2005			✓															
HEI-2010			✓	✓	✓									✓				
AHEI						✓	✓						✓					

Name of index	Energy	Total fat	Saturated fat	Polyunsaturated fat	Monounsaturated fat	MUFA/SFA:PUFA	Trans fatty acids	Cholesterol	Protein	Carbohydrates	Mono-saccharides/ disaccharides	Dietary fibre	Alcohol	Sodium	Calcium	Iron	Vitamin C	Beta-carotene
Canadian-HEI		✓	✓					✓						✓				
DQS		✓	✓															
DGAI		✓	✓				✓	✓				✓	✓	✓				
HFNI			✓	✓	✓			✓	✓	✓		✓						✓
ODI-R								✓						✓				
DGI-a		✓	✓					✓					✓	✓				
DGI-b													✓	✓				
Aussie-DQI			✓								✓		✓	✓				
HEIFA-2013			✓											✓				

AHEI, Alternate Healthy Eating Index; AES FFQ, Australian Eating Survey; Aussie-DQI, Australian Diet Quality Index; Aust-HEI, Australian Healthy Eating Index; ARFS, Australian Recommended Food Score; Food Frequency Questionnaire; Canadian-HEI, Canadian Healthy Eating Index; CHD, Coronary Heart Disease; CVD, Cardiovascular Disease; DGI-a, Dietary Guidelines Index; DGI-b, Dietary Guideline Index; DGAI, Dietary Guidelines for Americans Index; DQI-a, Diet Quality Index Alternative; DQI, Diet Quality Index; DQI-C, Chinese Diet Quality Index; DQI-I, Diet Quality Index International; DQS, Diet Quality Score; FFQ, Food Frequency Questionnaire; FHQ, Food Habits Questionnaire; HEI, Healthy Eating Index; HEI-2005, Healthy Eating Index – 2005; HEIFA-2013, Healthy Eating Index for Australian Adults; HFI, Healthy Food Index; HFNI, Healthy Food and Nutrient Index; LDL, Low-Density Lipoproteins; ODI-R, Overall Dietary Index Revised; NZDQI-A, New Zealand Diet Quality Index for Adolescents; NZAFFQ, New Zealand Adolescent Food Frequency Questionnaire; RFS, Recommended Food Score; SF, Saturated Fat; SDQ, Short Dietary Questions; Simple Diet Quality Index; USDA, United States Department of Agriculture

Table 2.5 Foods, food groups, and other measures of diet quality used as components in previous diet quality indices

Name of index	Fruit and vegetables	Fruit	Vegetables	Legumes (and nuts)	Grains	Whole grains	Meat (and meat products)	Trimming fat off meat	Lean meats	Processed meats	Fish	Milk and milk products	Type of milk	Potatoes	Fats/oils	High fat/high sugar foods	Fluids	Water	Alcohol	Dietary variety/diversity	Dietary moderation
DQI	✓				✓																
DQI-R		✓	✓		✓															✓	✓
DQI-C	✓																			✓	
DQI-I																					
DQI-a		✓	✓		✓		✓					✓		✓	✓						
SDQI																					
HEI		✓			✓		✓					✓								✓	
HEI-2005		✓	✓	✓	✓	✓						✓			✓					✓	✓
HEI-2010		✓	✓	✓							✓	✓									
Canadian-HEI	✓				✓							✓								✓	
DGI-a		✓	✓			✓	✓					✓									

Name of index	Fruit and vegetables	Fruit	Vegetables	Legumes (and nuts)	Grains	Whole grains	Meat (and meat products)	Trimming fat off meat	Lean meats	Processed meats	Fish	Milk and milk products	Type of milk	Potatoes	Fats/oils	High fat/high sugar foods	Fluids	Water	Alcohol	Dietary variety/diversity	Dietary moderation
DGAI		✓	✓	✓		✓	✓									✓					
HFNI	✓																				
HFI		✓	✓		✓								✓								
ODI-R		✓	✓			✓	✓	✓					✓				✓			✓	
Aust-HEI		✓	✓				✓	✓					✓			✓					
ARFS		✓	✓	✓	✓		✓											✓			
DGI-b		✓	✓		✓	✓	✓	✓	✓			✓	✓			✓	✓	✓	✓	✓	
Aussie-DQI		✓	✓		✓		✓			✓										✓	
HEIFA-2013		✓	✓			✓	✓					✓				✓		✓	✓		
NZDQI-A		✓	✓		✓		✓					✓								✓	

AHEI, Alternate Healthy Eating Index; AES FFQ, Australian Eating Survey; Aussie-DQI, Australian Diet Quality Index; Aust-HEI, Australian Healthy Eating Index; ARFS, Australian Recommended Food Score; Food Frequency Questionnaire; Canadian-HEI, Canadian Healthy Eating Index; CHD, Coronary Heart Disease; CVD, Cardiovascular Disease; DGI-a, Dietary Guidelines Index; DGI-b, Dietary Guideline Index; DGAI, Dietary Guidelines for Americans Index; DQI-a, Diet Quality Index Alternative; DQI, Diet Quality Index; DQI-C, Chinese Diet Quality Index; DQI-I, Diet Quality Index International; DQS, Diet Quality Score; FFQ, Food Frequency Questionnaire; FHQ, Food Habits Questionnaire; HEI, Healthy Eating Index; HEI-2005, Healthy Eating Index – 2005; HEIFA-2013, Healthy Eating Index for Australian Adults; HFI, Healthy Food Index; HFNI, Healthy Food and Nutrient Index; LDL, Low-Density Lipoproteins; ODI-R, Overall Dietary Index Revised; NZDQI-A, New Zealand Diet Quality Index for Adolescents; NZAFFQ, New Zealand Adolescent Food Frequency Questionnaire; RFS, Recommended Food Score; SF, Saturated Fat; SDQ, Short Dietary Questions; Simple Diet Quality Index; USDA, United States Department of Agriculture

2.6.1.2 Index components – foods and food groups

Table 2.5 highlights foods, food groups, and other measures of diet quality used as components in DQIs based on dietary guidelines. As expected, these indices tend to reflect all the major food groups (Guenther et al., 2014; McNaughton et al., 2008; Zarrin et al., 2013). Adequate consumption of fruit and vegetables is recommended by the majority of dietary guidelines. All indices incorporated fruits and vegetables as a component, either grouped together (Bazelmans et al., 2006; Garriguet, 2009; Patterson et al., 1994; Stookey et al., 2000) or separately (all other DQIs). It has been suggested that given the significant role of fruit and vegetables in the diet, they should be separate index components (Waijers et al., 2007). In addition, total grains are often used as a component. Unfortunately, many indices do not distinguish between whole grains and refined grains; therefore the importance of whole grains is not fully reflected (Waijers et al., 2007). Some indices have taken this into consideration, for example the DGI which determines the proportion of whole grains relative to the total amount of grains consumed (McNaughton et al., 2008). As whole grains are a good source of dietary fibre and associated with reduced risk of CHD and Type 2 diabetes (Arvaniti & Panagiotakos, 2008), they should be included in the index.

Dairy, alcohol, and meat tend to be more complex components of dietary indices (Waijers & Feskens, 2005). Dairy products, particularly full-fat items such as whole milk are high in saturated fat (Astrup et al., 2011). For this reason, high fat and low fat dairy products should be distinguished between one another (Waijers et al., 2007). Type of milk consumed was used a component in the DGI-b (McNaughton et al., 2008). Moreover, because meat and alcohol have a U-shaped association with health (i.e. can be beneficial or detrimental) it is potentially difficult to determine their value in an index (Waijers et al., 2007). As dietary guidelines generally do not advocate the consumption of alcohol (Ministry of Health, 2015b), indices deem alcohol to have negative impact on diet quality (Fogli-Cawley et al., 2006; Guenther, Reedy, & Krebs-Smith, 2008). Some DQIs have gone a step further and used components such as trimming fat off meat (Australian Institute of Health and Welfare, 2007; Lee et al., 2008), or include the amount of lean meat consumed relative to total meat (McNaughton et al., 2008).

2.6.1.3 Index components – Dietary variety

Dietary variety has been included as a component in some indices (Kennedy et al., 1995; Lee et al., 2008). Dietary variety can either reflect the total number of foods consumed (Kennedy et al., 1995) or variation in intake of foods within a food group consumed over a period of time (Australian Institute of Health and Welfare, 2007; Kim et al., 2003). Waijers et al (2007) argued that the use of dietary variety as an additional component is superfluous given most DQIs indirectly assess variety

through the inclusion of other food groups. However, a varied diet is highly recommended by most dietary guidelines, as it is associated with an increased intake of nutrients and non-nutrients and has been linked to improved chronic disease risk (Australian Institute of Health and Welfare, 2007; Harnack et al., 2002). Dietary variety has been determined in different ways depending on the index. For example, variety was defined as at least one serving from each food group in the Canadian-HEI (Shatenstein et al., 2005), whereas in the New Zealand Diet Quality Index for Adolescents, it was calculated as the proportion of foods consumed from within the four main food groups each week (Nour et al., 2014).

2.6.3 Assigning foods to selected components

If food groups are used, then foods need to be selected and assigned to designated food groups. The dietary guidelines upon which the index is based upon provide a guideline for this process. Some food groupings may be easier to develop than others. Unlike the addition of apples or oranges to the fruit group, assigning other foods may not be as straightforward. For instance, the DQI included all fruit, vegetables, dried foods, and mixed foods containing fruits and vegetables, but excluded unhealthy foods such as apple pie or potato chips in the fruit and vegetable group (Patterson et al., 1994). However, only a few indices provide insight into how food groupings are determined (Australian Institute of Health and Welfare, 2007; Wong et al., 2013; Zarrin et al., 2013).

When creating food groups, it is important to keep in mind that this process will be influenced by the dietary assessment method used to calculate the dietary score. Food frequency questionnaires may have a limited amount of foods and food groups, whereas diet histories include a wider range (Waijers & Feskens, 2005).

2.6.4 Scoring and cut-off points

Two types of components are treated differently in the scoring systems used in DQIs: desirable components such as fruits and vegetables, and undesirable component such as saturated fat, sugar, and sodium (Wirt & Collins, 2009). As a general rule, diet quality scores increase with higher intakes of desirable foods and decrease with intakes of undesirable foods. Dietary components selected are then quantified using cut-off points used to score the index. In most instances, indices use quantitative measures in the dietary guidelines, where possible, to guide the selection of cut-off points (Harnack et al., 2002; Waijers et al., 2007). The criteria used for cut-off points is usually the recommended number of servings for food groups (e.g. fruit, vegetables, grains, milk products, and meat and meat alternatives) (McNaughton et al., 2008), and use of recommendations such as the NRVs for nutrients (Patterson et al., 1994). Median intakes of participants have previously been

used, but only in the Mediterranean Diet Scores and its derivatives that are not investigated in this review (Trichopoulou et al., 1995). This makes the process of establishing cut-off points easier, as scoring for each component corresponds to the degree of adherence to the dietary guidelines.

Five different methods have been identified for determining cut-off points of selected components: (1) use of one cut-off point for the recommended level of all components (e.g. score of 0 if intake is less than cut-off, or score of 1 if intake is equal to or higher than cut-off value (Bazelmans et al., 2006; Löwik et al., 1999; Osler et al., 2001); (2) specific cut-offs for maximum and minimum intake for each component and calculating the intermediate scores proportionately (Kennedy et al., 1995) (3) establishing three cut-off ranges, including a low, intermediate, and an upper level (Australian Institute of Health and Welfare, 2007; Kennedy et al., 1995; Lee et al., 2008); (4) presenting the score based on percentage of total energy intake (Guenther, Reedy, & Krebs-Smith, 2008) and (5) no established cut-off point for the included components; the components are scored based on the reported consumption of any amount of the component, or alternatively no consumption (Collins et al., 2015; Kant et al., 2000).

Use of a small scoring scale has been considered disadvantageous, as the majority of individuals may fall below the cut-off point resulting in only a small number of participants meeting the recommendations (Bazelmans et al., 2006; Wirfält et al., 2013). Therefore, constructing an index with only a small number of partitions may result in loss of information (Kourlaba & Panagiotakos, 2009a). Use of multiple partitions allows the total score to more accurately represent how closely individuals align with the recommendations, particularly for those individuals with intakes near the cut-off points (Kourlaba & Panagiotakos, 2009a; Waijers et al., 2007).

Furthermore, some scoring systems include a penalty score for overconsumption (Fogli-Cawley et al., 2006; Waijers et al., 2007). For example, to emphasise the importance of moderation in fat intake, the Aussie-DQI penalised participants who consumed more than the recommended number of servings for milk and milk products, meats and processed meat (Zarrin et al., 2013). If overconsumption occurred, the minimum score was given to participants.

2.6.5 Adjustment for energy intake

An issue that needs to be addressed is whether to adjust the diet quality score for energy intake. As nutrient intake is associated with energy intake, a DQI could overrate diets that are high in energy (Guenther, Reedy, Krebs-Smith, & Reeve, 2008). Individuals with higher energy needs such as males, athletes, and certain age groups will obtain recommendations for food group servings much more easily, thereby increasing energy intake. As a result, it will appear these individuals have a higher

diet quality score, but in reality they exceed dietary guidelines due to their higher energy requirements (Waijers et al., 2007). Likewise individuals who consume more food than required will have the same outcome. Dietary variety has the same issue, as a higher energy intake is often associated with an increased variety of foods consumed (Waijers & Feskens, 2005). Adjustment for energy intake is considered in some DQIs, in which the number of recommended servings is set at an appropriate energy intake level, based on age and gender (Guenther, Reedy, Krebs-Smith, et al., 2008; Kennedy et al., 1995; Shatenstein et al., 2005). The DQI-I goes one step further and uses three levels to categorise energy intake for the main food groups (Kim et al., 2003). However, correlations with diet quality scores have been shown to be independent of energy intake (Guenther et al., 2014).

2.6.6 Contribution of each index component to the total score

Another consideration during the development of a DQI is the weighting of index components. Most indices developed are mutually weighted, in other words each component is given the same weight and contribute equally to the total score (Waijers et al., 2007). Some indices assign different weightings to components (Guenther, Reedy, & Krebs-Smith, 2008; McCullough et al., 2000; Shatenstein et al., 2005). The most common reason for an unequal weight system was that aspects of the index have different impacts on health. Linking the weights of components to the health outcome of interest has been recommended by several reviews of DQIs (Arvaniti & Panagiotakos, 2008; Vandevijvere et al., 2013). Therefore, higher weights were given to components more important to diet quality, based on dietary guidelines (Kourlaba & Panagiotakos, 2009a). For example, in the Overall Dietary Index Revised (ODI-R), 10 points were allocated to the grains and starchy foods component, whereas 5 points were given to the percentage of whole grains component (Lee et al., 2008).

2.6.7 Dietary data used

The most common dietary assessment methods used to establish dietary indices are taken from 24-hour recalls, food records, and FFQs. With respect to 24-hour recalls, due to day to day variation in dietary intakes, multiple days are required to ensure the index is holistic (Moeller et al., 2007; Shatenstein et al., 2005). Although multiple, non-consecutive food records are highly accurate, these methods are costly (Block & Hartman, 1989). Therefore, newly developed diet quality indices have used FFQs to assess usual diet quality. A few of these indices are based on short FFQs (Kant et al., 2000; Osler et al., 2001; Toft et al., 2007). The type of data obtained from FFQs has been considered more meaningful, however, it is important to note that FFQs may limit food groupings and alter food choice (Moeller et al., 2007). As this could result in mis-classification of participants, it is important

that the method used is accurate (Moeller et al., 2007). The FFQs used in dietary indices are primarily from national nutrition surveys (Guenther, Reedy, & Krebs-Smith, 2008; McNaughton et al., 2008), and none are specifically designed to be directly used for the purpose of a DQI.

2.7 Validation approaches in diet quality indices

Validity refers to the extent to which a method or tool measures what it was supposed to measure (Gibson, 2005; Thompson & Subar, 2008). As each dietary assessment method has its advantages and limitations, no method is free of error when estimating dietary intake (Gibson, 2005). The same applies to DQIs, as the methodological issues surrounding indices will affect their validity when assessing diet quality (Waijers et al., 2007). Therefore, it is essential that DQIs are validated prior to use. If dietary assessment methods are not accurately measured, this may lead to false associations between diet, health and disease (Cade et al., 2002; Thompson & Subar, 2008). Independent tests of validity are therefore essential to ensure findings of a study accurately represent the true circumstance or situation (Biro et al., 2002). Most published indices have used nutrient adequacy only as a validation method. The rest have been validated against anthropometric, biochemical and clinical measures of nutritional status (Kant, 1996). Even fewer DQIs have been validated against an independent reference method (e.g. food record) (Wong et al., 2013). An explanation for lack of validation measures is because the validation procedure is a time-consuming and expensive process. Within the literature, three forms of validity have been identified: content, construct and criterion validity (Kaplan et al., 1976; Streiner et al., 2014).

2.7.1 Content validity

This type of validity depends on whether the instrument represents all dimensions of content that it was supposed to measure (Kaplan et al., 1976; Kimberlin & Winterstein, 2008). As there is no statistical test to determine content validity, it depends on the researchers judgement (Kimberlin & Winterstein, 2008). In the diet quality context, content validity examines qualitatively the extent to which an index addresses aspects of diet quality specified in dietary guidelines (Guenther, Reedy, Krebs-Smith, et al., 2008). Although content validity of indices appears to have been considered in selection of components and researchers have tried to select the components of indices based on their purposes, only a few studies have reported on a systematic evaluation of content validity (Guenther, Reedy, Krebs-Smith, et al., 2008; Stookey et al., 2000). To achieve this, components included in the index are checked against dietary guidelines.

2.7.2 Construct validity

Construct validity examines the relationships between the instrument and variables known to be related to the index (Kaplan et al., 1976). The variables evaluated may be measures of behaviours or characteristics of an individual. With respect to DQIs, this is carried out by distinguishing between groups with known differences in diet quality (Guenther, Reedy, Krebs-Smith, et al., 2008). This is usually based on characteristics such as food and nutrient intake, demographic information, socioeconomic position, and health behaviours.

The most common approach used to assess construct validity of DQIs is the relationship between the observed score, and intakes of desirable or undesirable foods and nutrients (Wong et al., 2013). The majority of indices based on dietary guidelines utilise this type of validity (Australian Institute of Health and Welfare, 2007; Wong et al., 2013). The expected result is that an increase in the intake of favourable dietary components will be associated with an increased diet quality score. For example, when comparing nutrient intakes across the tertiles of NZDQI-A score, those in the highest tertile for NZDQI-A scores had higher intakes of iron and lower intakes of total fat, saturated fat, and monounsaturated fat than participants in the lowest tertile (Wong et al., 2013).

Other approaches to assess construct validity of dietary indices involve the use of demographic and health status or behaviours. Women generally have higher diet quality scores than men (Fogli-Cawley et al., 2006; Lee et al., 2008; McNaughton et al., 2008; Toft et al., 2007), and a positive relationship between age and diet quality has also been observed in many diet quality indices (Fogli-Cawley et al., 2006; Kant et al., 2000; Toft et al., 2007). There is a strong relationship between income level and diet quality scores (Hann, Rock, King, & Drewnowski, 2001; McNaughton et al., 2008). Indices such as the Aussie-DQI and DGI have assessed validity using The Index of Relative Socioeconomic Disadvantage (SEIFA) which is based on socioeconomic variables such as economic resources, occupation, education and ethnicity. These have found a lower socioeconomic position is associated with a lower diet quality score (Australian Institute of Health and Welfare, 2007; McNaughton et al., 2008).

In addition, construct validity has been assessed through health status or behaviours. For example, anthropometric measures such as body mass index (BMI) are commonly correlated with DQI scores. In some studies, BMI was inversely associated with diet quality scores (Fogli-Cawley et al., 2006; Hann et al., 2001; Harnack et al., 2002; Toft et al., 2007), whereas in other studies there was a positive association (McNaughton et al., 2008). Other studies have found no association (Toft et al., 2007). The association between blood pressure and diet quality has also been reported. However, there are inconsistent findings, as the DGI showed individuals with poor diet quality scores were

more likely to have higher blood pressure (McNaughton et al., 2008), whereas the Aust-HEI found no correlation (Australian Institute of Health and Welfare, 2007). In the Aust-HEI, the lack of correlation was put down to the fact that blood pressure is well managed in Australia with medication (Australian Institute of Health and Welfare, 2007).

The Healthy Eating 2005 compared the diet quality of smokers to non-smokers (Guenther, Reedy, Krebs-Smith, et al., 2008). Several studies have shown smokers are more likely to have lower diet quality scores than non-smokers (Fogli-Cawley et al., 2006; Stookey et al., 2000). Other health behaviours that have been used to assess the validity of dietary indices include physical activity (Lee et al., 2008; McNaughton et al., 2008; Toft et al., 2007), alcohol consumption (Kant et al., 2000; Lee et al., 2008), use of supplements (Fogli-Cawley et al., 2006; Hann et al., 2001; Kant et al., 2000), and history of heart disease, diabetes, or cancer (Kant et al., 2000; Lee et al., 2008).

2.7.3 Relative validity

Relative (or criterion) validity is assessed by comparing the outcome of an instrument to a standard accepted as truth (Kaplan et al., 1976; Streiner et al., 2014). There are two types of validity: concurrent and predictive validity. Concurrent validity occurs when a proposed measure is matched to a criterion at the same time. In contrast, predictive validity is when the proposed measure forecasts a criterion value (Kaplan et al., 1976). Both types of relative validity are based on the extent to which test scores and criterion scores are correlated.

The validation of a dietary assessment is usually carried out to assess whether a newly developed index (“test” instrument), agrees with an independent dietary method (“reference” instrument) (Cade et al., 2002). An example of relative validity used in dietary assessment methods is illustrated by Beck et al (2013), where a four-day weighed food record (“reference” dietary assessment method) was used to determine the validity of an iron FFQ (“test” dietary assessment method). Another approach is to use biomarkers as independent measures of relative validity (Gibson, 2005). For example, biomarkers used as an indicator of fruit and vegetable intake include serum folate, vitamin C and E, and carotenoids (Hann et al., 2001; Weinstein et al., 2004).

2.7.3.1 Key considerations in relative validity studies

There are several aspects that should be taken into account in the design of relative validity studies. The sample size of participants needs to be considered, and is dependent on the type of statistical methods used. With respect to correlation coefficients, a sample size of 100 to 200 participants is acceptable (Cade et al., 2002). Once the participants have been selected, it is also important that participant characteristics (e.g. age and gender) on which the index is based upon, represents the

population under examination (Gibson, 2005). As responses to dietary assessment methods differ between men and women, relative validity should be tested on genders separately (Gibson, 2005). Use of volunteers as the study population has been suggested, as this may lead to more accurate responses (Riboli, Elmståhl, Saracci, Gullberg, & Lindgärde, 1997). However, this may also be beneficial as volunteers have been shown to be more compliant (Edelstein, 2014). In addition, the purpose and measures of the test method needs to be the same as the reference method (Fernández-Ballart et al., 2010; Gibson, 2005). The two dietary methods are required to assess diet over the same time frame, whether it is current, past or usual intake (Cade et al., 2002; Fernández-Ballart et al., 2010). Furthermore, the sequence of administration of the test and reference methods should be taken into account. It has been suggested that the test method should be implemented prior to the reference method in order to imitate the proposed study (Cade et al., 2002; Gibson, 2005). This is done to avoid influencing the response to the test dietary assessment (Gibson, 2005). If the time period between the two dietary methods is a long duration, then seasonal effects will be introduced as a confounding factor in assessing dietary intake.

2.7.3.2 Use of relative validity in diet quality indices

In the diet quality context, relative validity has been used to observe associations with index scores and health outcomes. One of the primary outcomes that have been widely studied by many researchers is the role of diet and risk of mortality. For instance, the Healthy Food and Nutrient Index was related to all-cause mortality, (Bazelmans et al., 2006) and specific disease-cause mortality such as the reduced risk of cardiovascular disease or cancer mortality has been associated with the Recommended Food Score (RFS) (Kant et al., 2000). On the subject of the RFS, it is the most validated index available, as it has been validated with many different health outcomes such as chronic disease risk (McCullough et al., 2002), markers of inflammation (Fung et al., 2005).

As indicated above, there are many ways diet quality indices have been validated. However, there are limited studies that have validated DQIs (particularly those based on dietary guidelines and that include women) by comparing the scores obtained from the index against a reference standard (i.e. another dietary assessment method) (Román-Vinas et al., 2009). The majority of indices have been validated by using the same instrument used to create the index, which potentially leads to an over-estimation of validity (Wong et al., 2013). For example, Collins et al. (2015) used the same FFQ from which it was derived to validate the ARFS. As previously mentioned, the reference method should ideally be a dietary assessment method with uncorrelated errors (Gibson, 2005).

From the literature, only a few dietary indices based on dietary guidelines validated DQIs with an independent reference method (Newby et al., 2003; Toft et al., 2007; Wong et al., 2013). The Diet Quality Score aimed to validate a 48-item FFQ against a 198-item FFQ in order to develop a simple tool to assess diet quality (Toft et al., 2007). Dietary intakes from the 198-item FFQ was used to evaluate whether the DQS reflected diet quality (Toft et al., 2007). In another study by Wong et al (2013), the NZDQI-A derived from a short food questionnaire was validated against a four-day estimated food record. Moreover, the DQI-R was validated using data from two FFQs against a food record (Newby et al., 2003).

2.8 Statistical analysis

The validity of a diet quality index needs to be assessed using statistical techniques. Currently, there is no consensus on the most appropriate statistical methods to analyse the validity of DQIs. Commonly used methods include correlation coefficients, linear trend analysis, linear regression models, and cross-classification.

The majority of studies have used correlation coefficients to determine the validity of DQIs. Pearson's correlation coefficients are used for normally distributed data, and Spearman's rank correlation coefficients for data that is not normally distributed (Masson et al., 2003). In construct validity, correlation coefficients are often calculated to evaluate the relationship between the total diet quality score and food and nutrient intakes (Collins et al., 2015; Fogli-Cawley et al., 2006; Stookey et al., 2000; Roy et al., 2015). Moreover, linear trend analysis evaluates the ability of diet quality scores to rank participants by nutrient intakes across categories. This is usually done using the distribution of scores (e.g. tertiles) as the continuous variable, and nutrient intakes as the dependent variable (Benítez-Arciniega et al., 2011). If the outcome measure of DQIs is not nutrient adequacy, many indices used linear regression analysis. This method has been used to examine associations between diet quality scores and factors such as socio-demographic variables and health behaviours (McNaughton et al., 2008; Toft et al., 2007).

Many studies use a range of statistical methods to assess relative validity (i.e. agreement between a DQI and reference method) (Masson et al., 2003; Wong et al., 2013). The DQS used Spearman's correlation coefficients to examine the associations between the DQS and food and nutrient intakes. Correlation coefficients between the DQS and 198-item FFQ varied between dietary components, ranging from 0.55 (fruit) to 0.05 (vitamin A) (Toft et al., 2007). In addition, for the NZDQI-A, correlations between the NZDQI-A scores derived from the FFQ relative to those derived from the food record were compared. It was found that both methods had fair agreement at ranking the

NZDQI-A score (r = 0.39) (Wong et al., 2013). Cross-classification was also used in this study to assess agreement between the two dietary methods in ranking participants. Cross-classification analysis identifies the percentage of participants correctly classified into the same category, or grossly misclassified into the opposite category after grouping participants (Masson et al., 2003). Correct classification into the same tertile should occur for >50% participants, and misclassification should occur for <10% of participants (Cade et al., 2002; Masson et al., 2003). The results showed that more than 50% of the participants were classified into the same thirds while 10% were misclassified into the opposite thirds (Wong et al., 2013).

Other statistical methods used to assess the validity of dietary assessment methods include comparison of group means or medians, whereby paired t-tests are used for parametric data and the Wilcoxin signed rank test is used for non-parametric data (Cade et al., 2002). Although cross-classification has been used before to validate DQIs (Wong et al., 2013), the percentage of agreement includes agreement that may occur by chance (Cade et al., 2002; Willet, 1998). For this reason, Cohen's weighted kappa statistic is calculated to provide a summary measure of agreement in cross-classification analysis (Cade et al., 2002; Gibson, 2005). Furthermore, the Bland and Altman method can be used to validate a dietary assessment method against a reference method using limits of agreement (Bland & Altman, 1999). This method measures the agreement between two dietary methods, but also determines whether the difference between dietary methods is the same across a range of nutrient intakes. This is done by plotting the difference of the dietary assessment methods against the mean of the two dietary methods (Bland & Altman, 1986). Few studies have used the Bland and Altman method to assess the validity of DQIs. In the Healthy Eating Index for Australian adults (HEIFA-2013), measures of agreement such as the weighted kappa and the Bland Altman were used to between the HEIFA-2013 and a food record (Roy et al., 2015).

2.9 Summary

Young women have been shown to consume more energy dense and nutrient poor foods, resulting in higher rates of obesity in New Zealand. To assess associations between diet, health, and disease, traditional dietary assessment methods such as food records, 24-hour recalls, FFQs, and diet histories have been used. Although many dietary assessment methods exist, they tend to focus on individual nutrients as opposed to whole foods. In light of this, dietary patterns offer an alternative approach. There are two types of methods used to analyse dietary patterns: statistical techniques such as factor and cluster analysis, (also known as data driven approaches), and diet quality indices that are based on dietary guidelines. Diet quality indices allow diet to be measured as a single exposure. They have become widespread in Western countries such as America, Europe, and

Australia. In these areas, DQIs have been shown to assess overall diet quality and adherence to dietary guidelines. However, given that the purpose of the index plays a significant role in the development and validation of DQIs, it is important the index is adapted to the specific needs of the country in which it is based, and to the characteristics of the population group. In the construction of an index, many any researcher decisions are required such as selection of components, cut-off points, and scoring method. Once a total score has been produced, DQIs can be associated with nutrient intakes and other health outcomes. There are three different types of methods to evaluate the validity of an index: content, construct, and relative validity. However, there is a lack of consensus regarding the best way to validate DQIs.

3. Methodology

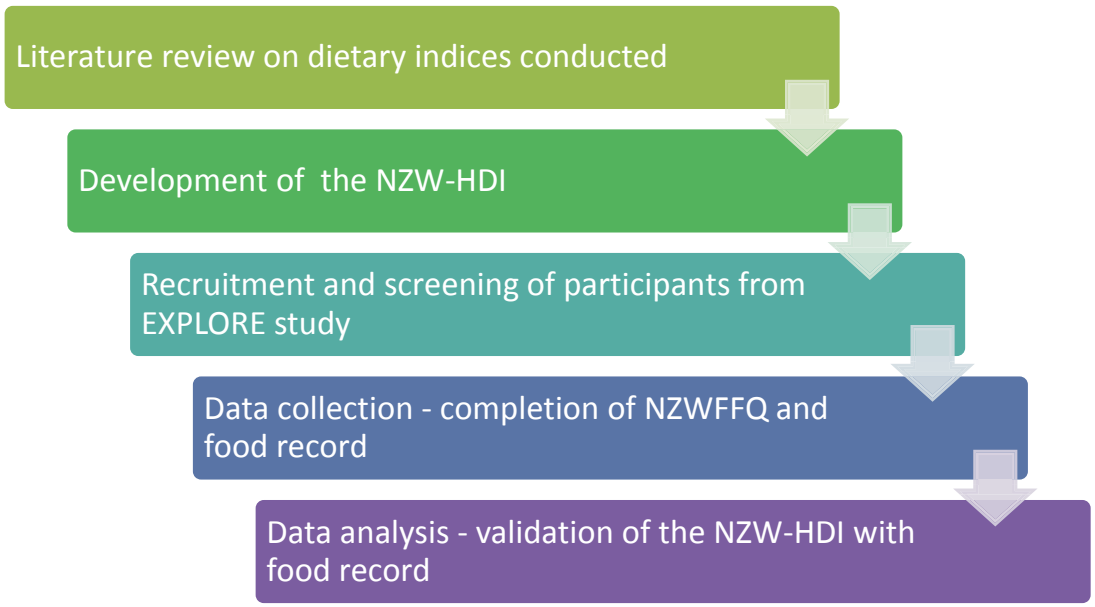
3.1 Study design

This thesis was designed as a cross-sectional validation study, using a subsample of young women from the Women's EXamining Predictors Linking Obesity-Related Elements (EXPLORE) study. Briefly,

the EXPLORE study aims to find out how different weight (body mass index) and body fat profiles are linked to chronic disease in young women (Kruger et al., 2015). The study also further investigates the association between body composition profiles, lifestyle factors (diet and physical activity), and gene expression of microRNA. Further details of the EXPLORE study can be seen in the publication by Kruger et al (2015).

The five key stages involved in the development and validation of the New Zealand Women's Healthy Diet Index (NZW-HDI) are outlined in Figure 3.1. Information obtained from dietary intake data in the Women's EXPLORE study has been used in the development and validation of the NZW-HDI. Participants completed the New Zealand Women's Food Frequency Questionnaire (NZWFFQ) that assisted in the development process of the NZW-HDI, and a four-day food record which was the reference method used to validate the NZW-HDI. The data from the NZWFFQ and food record were collected over a one year period – between July 2013 and July 2014, which ensured seasonal dietary changes were reflected.

Figure 3.1 Stages involved in the development and validation of the New Zealand Women's Healthy Diet Index



3.2 Ethical approval

This study protocol was reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 13/13. Young women interested in participating were given an information sheet explaining the study, and written informed consent was obtained from all participants.

3.3 Study population

3.3.1 Eligibility

Inclusion criteria into the Women's EXPLORE study required participants to be post-menarcheal or pre-menopausal (defined as having a regular menstrual cycle for more than one year), and one of three different ethnicities (defined as having one parent from European, Māori, and Pacific Island descent, or self-identification) (Kruger et al., 2015). Participants were also required to be 16 – 45 years old. However, in the present study, only participants aged 19 years and over were included. This is because the Eating and Activity Guidelines for New Zealand Adults (EAGNZA), upon which the NZW-HDI is based, are specifically aimed at this age group (Ministry of Health, 2015b). Women were excluded if they were currently pregnant, lactating, or presented with a chronic disease such as diabetes or heart disease.

3.3.2 Sample size

When validating any new dietary assessment tool, a sample size of more than size 100 participants is recommended (Cade et al., 2002; Thompson & Byers, 1994). Previous research validating DQIs against food records has been conducted on sample sizes ranging from 41 (Wong et al., 2013), to 8719 participants (Kant & Graubard, 2005).

3.4 Recruitment

Participants were obtained through convenience sampling in the Auckland region. Various modes of recruitment were utilised such as mass media (e.g. newspapers, radio, magazines, social networking websites), promotional flyers and posters distributed at schools, universities, businesses, organisations, events (e.g. at libraries, malls, and health and wellness events). In addition, culturally-specific methods were used to recruit Māori and Pacific Island young women. Cultural advisors were appointed to establish effective strategies to help with the recruitment of these ethnic groups. A key strategy was creating relationships with community leaders of each respective ethnicity in order to promote participation in the study. Within Māori and Pacific Island communities; sports teams, maraes, and churches were approached.

3.5 Screening

Young women interested in participating in the study were given an information sheet and required to complete a screening questionnaire, which could be completed online via the EXPLORE study website or on a paper copy. The questionnaire included a health screen and questions that deemed eligibility into the study (e.g. ethnicity of participants).

Body composition of participants was then obtained for the Women's EXPLORE study. The measurements allowed researchers to categorise the participants into three body composition profile groups based on BMI and body fat percentage: normal weight (normal BMI, normal body fat) hidden fat (normal BMI, high body fat) and apparent fat (high BMI, high body fat). The body composition profile groups are not relevant for this study, and will not be further discussed. Weight and height of the participants was taken to calculate BMI (kg/m^2). Weight was measured using the electronic scales on the Bioelectrical Impedance Anaylsis (BIA) (Biospace, Inbody 230, Cerritos, CA) machine, and height was recorded with a stadiometer (SECA, Germany). As the BIA is a portable device, screening was conducted either at the Human Nutrition Research Unit (HNRU) at Massey University, or another location (Kruger et al., 2015).

3.6 Data collection

Participants who met the eligibility criteria for the EXPLORE study transitioned to the next phase of data collection. This required participants to visit the HNRU for approximately two hours to complete all testing stations. Upon arrival the study protocol was discussed with participants by a member of the research team. At this point, another questionnaire was completed by the participants regarding personal, health, and demographic information. In the EXPLORE study, participants were allocated to eight testing stations that included: body composition measured using the BIA, air displacement plethysmography analysis (BODPOD) (2007A, Life Measurement Inc, Concord, Ca., using software V4.2+ as supplied by the manufacturer), and dual x-ray absorptiometry (DXA) (Hologic QDR Discovery A, Hologic Inc, Bedford, MA. with APEX V. 3.2 software); blood samples; blood pressure; taste testing; three dietary questionnaires including the New Zealand Women's Food Frequency Questionnaire (NZWFFQ); and a take-home station - whereby participants were fitted with an accelerometer, and also provided with information on the completion of a dietary diversity questionnaire, physical activity diary for seven days, and weighed four-day food record (FR) (Kruger et al., 2015). The NZWFFQ and food record will be discussed in further detail as this data collection assisted in the development and validation of the NZW-HDI.

3.7 Dietary assessment tools

3.7.1 The New Zealand Womens' Food Frequency Questionnaire

Usual dietary intake of participants was assessed using the New Zealand Women's Food Frequency Questionnaire (NZWFFQ), a semi-quantitative food frequency questionnaire. The NZWFFQ was previously validated for nutrient intake in young women (Houston, 2014). Based on the 97/98 National Nutrition Survey food list, it contains foods unique to the NZ culture. The NZWFFQ consisted of 220 food items categorised into 16 sections. However, only certain sections were used for the development of the index. Sections used in the NZW-HDI included dairy; bread; breakfast cereals and porridge; starchy foods; meat; poultry; fish and seafood; eggs; legumes; vegetables; fruit; drinks; and takeaways. Refer to Appendix A for the NZWFFQ that was used in the development of the NZW-HDI.

A total of 14 questions from the NZWFFQ were used for the NZW-HDI. Where possible, summary questions from the NZWFFQ were used instead of frequency questions for simplicity purposes. Examples of summary questions were, 'how many servings of fruit do you eat per day?', 'how much takeaways do you have each week?'. If summary questions were not available, frequency of intake was calculated from a longer list of foods. For example, 'how often do you have the following milk products?' had a list of different types of milk products (e.g. milk as a drink, milk on breakfast cereals) that were used instead. For frequency questions, participants indicated the frequency that best described their intake over the past month. The response categories ranged from never, less than once a month, one to three times per month, once per week, two to three times per week, four to six times per week, once per day, two to three times per day, and four plus times per day. Standard serving sizes were based on the NZ food composition tables (Ministry of Health, 1998), and 'The Photographic Atlas of Food Portion Sizes' (Nelson, Atkinson, & Meyer, 1997). The quantity descriptions depended on the food item e.g. 1 slice of bread. Where possible, the serving size was kept consistent throughout the sections. For example, all breakfast cereals used ½ cup as a standard quantity. Additional frequency questions examined eating behaviours such as, 'how often do you remove the skin from chicken', or 'how often do you use salt at the table'. For these questions, participants selected from the response category (e.g. never, usually, or always).

Clear, verbal instructions by members of the EXPLORE research team were given to each participant in relation to completing the NZWFFQ. In order to ensure the delivery of instructions was consistent and accurate; researchers followed a standardised protocol from a Standard Operating Procedure (SOP) found in Appendix B. The NZWFFQ was primarily completed online using SurveyMonkey, an

online survey development programme. However, hardcopies of the dietary questionnaire for manual input were used as an alternative if any technical issues arose and could not be resolved. Use of an online format reduced the effect of fatigue, as it took less time to complete than a paper copy. This also ensured the NZWFFQ was fully completed, as participants could not progress to the next section if there were unanswered questions.

A research assistant explained key components of the dietary questionnaires e.g. what the FFQ intended to measure. To further explain the NZWFFQ, the researcher also assisted in two example questions on sugar and bread, two commonly consumed food items. This ensured participants understood what was required and familiarised them with the format of the questionnaire. The use of examples has been shown to minimise the errors that commonly occur within the first few questions of completing a FFQ (Cade et al., 2002). The time taken for participants to complete the NZWFFQ was approximately 25 minutes.

3.7.2 Weighed food record (reference method)

Selecting an independent reference method was imperative in the validation process of the NZW-HDI. The reference method needed to have independent measurement errors. The food record was chosen as the reference method for comparison with the NZWFFQ derived NZW-HDI, as unlike a 24-hour recall it is not dependent on memory, therefore has the least correlated errors with the index (Thompson & Subar, 2008).

Participants were required to complete a weighed four-day food record (FR). Prior to the commencement of the FR, participants were provided extensive training through the use of audio-visual and written instructions on food records. Refer to Appendix C for the Standard Operating Procedures used by researchers for food record instructions. Participants watched a video brief on how to keep a food record, which was developed by dietitians at the HNRU. Verbal instructions were also given by a member of the EXPLORE research team on the purpose of the food record, importance of accuracy, and the importance of maintaining a normal dietary intake. A take home pack consisting of a food record diary; electronic scales; and “The Food Record Guide” booklet by Nelson et al. (1997) were provided to all participants.

Participants were allocated four consecutive days in which to complete the food record by a researcher, who wrote the specific dates on the front of their food diary. Although Willett (1998) suggests the use of non-consecutive days to obtain within-person variability, this could not be achieved in this study as participants were required to record physical activity data for the wider EXPLORE study during this same period. The FR included three weekdays and one weekend day.

Dietary intake has been shown to change during the weekend (Biro et al., 2002; Willet, 1998), therefore, this allowed usual eating habits to be captured. In addition, the variation in the days allocated to participants meant all seven days of the week were covered. The FR was a hardcopy form that contained written instructions and examples to guide participants (see Appendix D).

Recording of intake started from the time the participant woke up until the last food or beverage was consumed. Participants were asked to record food and beverages immediately after consumption. Participants were instructed to record intake as follows: the time of each eating occasion, provide information on the food or beverage such as brand, type, and cooking method, and to specify the quantity consumed using appropriate food-specific units, household measures or scales. Electronic scales (Tanita KD-200) were given to participants to weigh food items as these are more accurate than kitchen scales, reducing measurement errors (Willet, 1998). It was advised that the use of weighing scales improved precision of the data, but the act was voluntary. Participants were encouraged to record recipes for home cooked meals, and attach pre-packaged foods to their food diaries to provide more detail.

The supplementary booklet given to participants assisted in recording intake in situations where participants were unable to use scales (e.g. takeaway or restaurant meals). The booklet was a photographic guide to illustrate portion sizes (Nelson, 1997). To allow participants to quantify consumption, each food or meal had eight different portion sizes to choose from. Each food item or meal was accompanied with a coded number and letter that participants could record in the food diary. As each code had an approximate portion size attached, this allowed the researcher to determine portion size.

Once the recording period had finished, participants returned the food records to the HRNU. Food records were checked by researchers to ensure they were fully completed. If any missing information was found, the participant was contacted to resolve any omissions before the food records were analysed.

3.8 Development of the New Zealand Women's Healthy Diet Index

The first step in the development of the NZW-HDI was to investigate previous research on dietary indices and methodology. The Dietary Guideline Index (DGI) developed by McNaughton et al. (2008) heavily influenced the construction of the NZW-HDI, as the guidelines in Australia are similar to those in New Zealand. Decisions were then made on the construction of the NZW-HDI, such as index components, cut-off points, and scoring. The final NZW-HDI was designed to assess overall diet quality, and to measure the adherence of young women aged 19-45 years to the Eating and Activity

Guidelines for New Zealand Adults (EAGNZA). The NZW-HDI had 17 index components consisting of fruit variety, vegetable variety, fruit, vegetables, grains, proportion of whole-grains, milk and milk products, the combined (legumes, nuts, seeds or fish, seafood, eggs, poultry or red meat), amount of red meat, type of milk purchased, trimming of meat/skin off chicken, salt use, sugary foods, fluids, proportion of water, and alcohol. If the guidelines were not met, a score of 0 was given to participants, whereas a score of 5 or 10 (depending on the component) was given to participants that completely adhered to the guidelines. Intermediate scores were given between the minimum and maximum score, and were based on the number of servings or cut-off points for each component. The total score was the sum of the 17 components that ranged from 0-115 with a higher score reflecting greater adherence to the guidelines.

3.8.1 Overview of EAGNZA

The Ministry of Health has recently released the new Eating and Activity Guidelines for New Zealand Adults (EAGNZA) for people aged 19–64 years (Ministry of Health, 2015b). For the purpose of the NZW-HDI, only sections from the Eating Guidelines were used as opposed to statements related to Activity and Body Weight. Table 3.1 shows the Eating Guideline for New Zealand Adults, with suggested recommendations. These guidelines provide a standard for evaluating diet quality as they are developed by nutrition experts on behalf of the Ministry of Health that review the evidence based on associations between dietary factors and chronic disease (Ministry of Health, 2015b). In addition, the guidelines are specific to New Zealand, can be quantified, and are ranked based on public health importance. The EAGNZA has recently been updated (released October, 2015), with the new guidelines reflecting current nutritional knowledge. The EAGNZA was essential in the development of the selection of NZW-HDI components, establishing cut-off points, and scoring.

Table 3.1 Eating Guidelines for New Zealand Adults

Eating Guidelines for New Zealand Adults	Key features	Recommendations
Enjoy a variety of nutritious foods including:	Plenty of vegetables and fruit	Eat at least three servings of vegetables per day
		Eat at least two servings of fruit per day
	Grain foods, mostly wholegrain and those naturally high in fibre	Eat at least six servings per day
	Some milk and milk products, mostly low and reduced fat	Eat at least two servings per day (choose low- or reduced fat options)
	Some legumes, nuts, seeds, fish, and other seafood, eggs, poultry, and/or red meat with the fat removed	Eat at least two servings of legumes, nuts and seeds per day OR
		Eat at least one serving of fish and other seafood, eggs, poultry or red meat per day
		Eat no more than 500 g cooked red meat each week
Choose and/or prepare foods and drinks:	With unsaturated fats, instead of saturated fats	Choose meat with little visible fat or remove fat before cooking
	That are low in salt (sodium); if using salt, choose iodised salt	Choose 'whole' or less processed foods that are low in sodium

Eating Guidelines for New Zealand Adults	Key features	Recommendations
Choose and/or prepare foods and drinks:	With little or no added sugar, and that are minimally processed	Choose foods with the lowest amount of added sugar
	Choosing or preparing whole and less processed foods	Prepare meals at home using whole and less processed ingredients
Make plain water your first choice over other drinks	Fluids (including plain water, milk)	8 x 250 ml cups of fluid per day
If you drink alcohol, keep your intake low Stop drinking alcohol if you could be pregnant, are pregnant or are trying to If you drink alcohol, keep your intake low Stop drinking alcohol if you could be pregnant, are pregnant or are trying to get pregnant	If you drink alcohol, keep your intake low	No more than two standard drinks a day and no more than 10 standard drinks each week for women[1] No more than three standard drinks a day and no more than 15 standard drinks each week for men[1] At least two alcohol free days every week for both women and men[1]

[1]A standard drink is a 330 ml bottle of beer, or 100 ml of wine, or 30 ml of straight spirit (each is equivalent to 10 g alcohol)

3.8.2 Scaling of components

As the NZW-HDI components are based on the guidelines, a weighting scheme was used to reflect the key guideline statements of the EAGNZA. The selected components weighted towards the total score as follows:

Table 3.2 Point system used for NZW-HDI individual components

Components	**Point system**
Variety	Two components, contributing 5 points each to the total score
Fruit and vegetables	These were made into two separate components, each contributing 10 points to the total score to reflect their importance as main food groups
Milk and milk products	Contributed 10 points to the total score as these are main food group
Grain foods	Contributed 10 points to the total score as these are main food groups
Legumes, nuts, seeds/kaimoana, eggs, poultry and red meat, grain foods, and milk components	Combined component Contributed 10 points to the total score as these are main food groups
Proportion of water consumed relative to total beverages	10 points each to the total score as these are key guideline statements
Proportion of whole grains, and proportion of water	Contributed 5 points each to the total score
Amount of red meat consumed per week, type of milk purchased, trimming fat off meat/skin off chicken, salt use, takeaway consumption each week, and high sugar foods consumed each week	Contributed 5 points each to the total score

Depending on the scale for the component, some were categorically scored as 0, 5 or 10, while others were continuous components from 0 to 10. As previously mentioned, intermediate scores were given between the minimum and maximum score, and were based on the number of servings or cut-off points for each component. Scaling of selected components reflected their relative impact on health. For example, positive associations such as increased fruit or vegetable intake increased the score, whereas negative associations such as takeaway consumption decreased the score.

3.8.3 Index components, scoring, and cut-off points

During the selection process of the NZW-HDI components, two key aspects were required. Firstly, all dietary information that makes up the index components needed to be available within the NZWFFQ. Secondly, index components had to be based on the EGSNZA. See Appendix C for assumptions and decisions made during the development of the index. Further details regarding the scoring of each component follow

Table 3.3 Components and scoring of the NZW-HDI

Description of the component	Score range	Criteria for minimum score	Criteria for maximum score
Variety: Number of coloured fruits in each category (red, orange/yellow, purple/blue, green, white/brown)	0-5	0	5
Variety: Number of coloured vegetables in each category (red, orange/yellow, purple/blue, green, white/brown)	0-5	0	5
Vegetables: Servings of vegetables per day	0-10	0	≥3
Fruit: Servings of vegetables per day	0-10	0	≥2
Grain foods: Servings of breads and cereals per day	0-10	0	≥6
Wholegrain foods: Proportion of wholemeal/wholegrain choices relative to total amount of breads and cereals	0-5	0%	100%
Milk and milk products: servings of milk and milk products per day	0-10	0	≥2
Legumes, nuts, seeds: Servings per day	0-10	0	≥2
OR		0	≥1
Fish, seafood, eggs, poultry or red meat: Servings per day			
Amount of red meat consumed	0-5	>500 g	≤500 g
Type of milk purchased	0-5	Whole milk	Low fat milk
Trimming of fat from meat, removal of skin from chicken	0-5	Never/rarely	Always

Description of the component	Score range	Criteria for minimum score	Criteria for maximum score
Salt: Salt used in cooking, salt used at the table	0-5	Always	Never/rarely
Takeaways: Takeaway consumption per week	0-5	≥3	≤1
Sugary foods (e.g. chocolate, cakes, biscuits): Number of servings from each category per week	0-5	≥3	≤1
Fluids: Frequency of consumption of beverages	0-10	0	≥8
Fluids: Proportion of water consumed relative to total beverages	0-5	0%	50%
Alcohol: Number of standard drinks per week	0-5	0	≥10
Total score	0-115	0	115

[1]The NZW-HDI components and criteria used for scoring system

[2]Participants only score on one component (dependent on which guideline is met)

Note. Proportional scores are computed for intakes situated between the maximum, median, and minimum criteria. Cut-off points are based on the EAGNZA

Variety component

The EGSNZA emphasises the importance of eating a range of food from the food groups. As the NZWFFQ did not measure variety, dietary variety for the index was defined as the number of different coloured fruit and vegetables consumed. In the case of diet quality, consumption of fruit and vegetables potentially a greater indicator of variety than variety of grain foods, milk and milk products, and legumes, nuts and seeds or fish and seafood, eggs, poultry and red meat. Coloured fruit and vegetables have been shown to have a decreased risk of cancer due to their anthocyans (Wang & Stoner, 2008). For this reason, fruit and vegetables were grouped on the basis of colouration and linked to their associated anthocyan. The colour groups were red (lycopene), orange/yellow (carotenoids), blue/purple (anthocyanins), green (chlorophyll), and white/brown (anthoxanthins) (Ministry of Health, 2015b; Wang & Stoner, 2008). As there was an uneven distribution of fruits and vegetables within each group, variety within each colour group was defined as consuming at least 1 serving from each fruit and vegetable colour group. Participants were given a score of 0 if they consumed less than one serving from each fruit and vegetable colour group, or a score of 1 if they consumed one serving, 2 for two servings and so on. For each fruit and vegetable variety score, a possible score of 5 could be achieved, which ranged from 0-5 points.

Fruit component

Fruit are part of one of the main food groups (fruit and vegetables) in the EGSNZA. This component is based on the summary question, 'on average, how many serves of fruit do you usually eat each day?' A score of 0, 5, or 10 was given to depending on the number of servings consumed. Recommended servings of fruit per day in the EGSNZA were used as cut-off points. For this component, 2 or more servings per day scored 10 points, 1 serving per day scored 5 points, and 0 servings per day scored 0 points.

Vegetable component

Vegetables are part of one of the main food groups (fruit and vegetables) in the EGSNZA. This component is based on the summary question, 'on average, how many serves of vegetables do you usually eat each day?' This component was a categorical variable, and scoring was determined by the number of servings consumed. Recommended daily servings of vegetables in the guidelines were used as cut-off points. For this component, 3 servings or more per day scored 10 points, 1-2 servings per day scored 6.66 points, and 0 servings per day scored 3.33 points.

Grains component

Grain foods are one of the main guideline statements. This component was based on three separate questions, 'on average, how many servings of bread do eat per day', 'on average, how many servings of breakfast cereal or porridge do you have per week?' , and 'on average, how many servings of starchy foods such as rice, pasta, noodles and couscous do you eat per week'. Responses were converted to servings per day and combined to provide a total number. The component was a continuous scale, and scoring was determined by the number of servings based on the guidelines. For this component, 6 or more servings per day scored 10 points, 5 servings per day scored 8.30 points, 4 servings per day scored 6.64 points, 3 servings per day scored 4.98 points, 2 servings per day scored 3.32 points, 1 serving per days scored 1.66 points, and 0 servings per day scored 0 points.

Proportion of whole grains component

The proportion of whole grains relative to the total number of grains was included in the index as the updated guidelines have a greater focus on whole grains compared with previous guidelines (Ministry of Health, 2015b). This component is based on the three questions used above for the grains component. From the list of breads, cereals, and starchy foods, whole grains such as brown rice were matched to their corresponding refined grain (e.g. brown rice vs white rice). This was done due to the fact there were more refined grains than whole grains, to ensure equal weighting towards the sub-score for this component. A score of 0, 2.5, or 5 was given depending on the proportion of whole grains consumed. For this component, consuming >75% whole grains scored 5 points, consuming 50% to 74.99% whole grains scored 3.75 points, consuming 37.5% to 49.99% whole grains scored 2.5 points, consuming 25% to 37.49% whole grains scored 1.25 points, and consuming 0% to 24.99% whole grains scored 0 points. Similar scoring and cut-off points were used in McNaughton et al (2008).

Milk and milk products component

Milk and milk products are one of the main food groups in the guidelines. Intake was based on the frequency questions, 'how often do you usually have milk?', 'how often do you usually eat cheese?', and 'how often do you usually eat these dairy based foods?'. Responses were converted to servings per day and combined to provide a total number. Recommended daily servings of milk and milk products from the EAGNZA were used as cut-off points. A score of 2 or more servings per day scored 10 points, 1 serving per day scored 5 points, and 0 servings per day scored 0 points.

Legumes, nuts, seeds, fish and other seafood, eggs, poultry, and red meat component

This component has two different components: (1) legumes, nuts, and seeds, and (2) red meat, poultry, fish and seafood, and eggs. Together, these make one of the main food groups in the EAGNZA. The first component is based on several questions including, 'on average, how many servings of legumes (fresh, frozen, canned, dried) do you eat per week?', and additional frequency questions on consumption of different types of nuts and seeds. The second component is based on four separate summary questions, 'on average, how many servings of meat e.g. beef, mutton, hogget, lamb or pork do you eat per week', 'on average, how many servings of chicken (all types including fresh, frozen, and tinned) do you eat per week', 'on average, how many servings of fish and seafood (all types including fresh, frozen, and tinned) do you eat per week', and 'on average, how many eggs do you eat per week?' Responses were first converted into daily number of servings, and then combined to provide a total number. A score of 0, 5, or 10 was given depending on the number of servings consumed. The recommended number of daily servings for these components from the EAGNZA was used as cut-off points. For legumes, nuts, and seeds, 2 or more servings scored 10 points, 1 serving per day scored 5 points, and 0 servings per day scored 0 points. For fish and seafood, eggs, poultry and red meat, 1 or more servings per day scored 10 points, 0.5 servings scored 5 points, and 0 servings per day scored 0 points. For this component, if participants did not meet guideline for fish and seafood, eggs, poultry and red meat (i.e. scored 0 points), the score from legumes, nuts, and seeds was used instead to account for vegetarians and vegans (and vice versa).

Red meat

Consumption of red meat was used as a component, due to the new dietary guidelines acknowledging the need to limit intake by suggesting to 'limit red meat to no more than 500 g per week'. This component was based on the question, 'on average, how many servings of meat e.g. beef, mutton, hogget, lamb or pork do you eat per week?' Responses were combined to provide a total number. For this component, the scoring was set to 0 or 5 points. Cut-off points were based on the EGSNZA red meat intake recommendations previously mentioned. For this component, ≤500 g of red meat per week scored 5 points, and >500 g of red meat per week scored 0 points.

Type of milk purchased

The EGSNZA advocate for choosing low fat milk products, therefore it was important to establish the type of milk participants purchased. In terms of type of milk consumed, other indices have used low fat milk and whole milk as criteria for the maximum and minimum score (McNaughton et al., 2008). However, this component was based on the question in the NZWFFQ of, 'what types of milk do you

have most often?', and participants could choose more than one option. For this reason, criteria included low fat milk, both types of milk, and whole milk, whereby participants scored 5, 2.5, and 0 points respectively.

Trimming fat off meat/skin off chicken component

This component was chosen as it is a recommendation in the EGSNZA in order to decrease saturated fat, and is based on two questions, 'do you trim any excess fat (fat you can see) off these meats?', and 'do you remove the skin from chicken?' Responses from each question were combined. Other indices have used the criteria as 'usually' or 'rarely' as maximum and minimum scores. However, the responses set in the NZWFFQ were 'always' that scored 5 points, 'often' scored 2.5 points, and 'occasionally or never' scored 0 points.

Salt use component

A recommendation in the EGSNZA is to use less salt at the table and in cooking. Similarly to the trimming fat off meat/skin off chicken component, salt use is based on two questions, 'do you use salt in cooking?', and 'do you use salt at the table', in which the responses from each question were combined. Previous indices have used 'never or rarely' and 'usually' as maximum and minimum scores for this component (McNaughton et al., 2008). For the NZW-HDI, 'never or rarely' scored 5 points, 'sometimes' scored 2.5 points, and 'always or usually' scored 0 points.

Takeaways component

A new recommendation in the guidelines is to limit takeaway consumption to once per week. This component is based on the question, 'on average, how often do you eat takeaways per week?' Scoring for this component ranged from 0, 2.5, and 5 points. Cut-off points were based on EAGNZA. A score of 5 points was given if takeaways were consumed ≤1 per week, a score of 2.5 was given if takeaways were consumed two times per week, and a score of 0 was given if takeaways were consumed ≥3 times per week.

Sugary foods component

The updated EGSNZA recommend limiting processed foods high in sugar to less than once a week. The high sugar food component is based on frequency questions that include, 'how often do you usually eat these other foods? (chocolate, cakes and muffins, sweet pies and pastries, biscuits, and lollies)' Responses were converted to intake per week. Scoring for this component ranged from 0, 2.5, and 5 points. A sugar intake of ≤1 serving per week was given 5 points, sugar intake of twice per week scored 2.5 points, and sugar intake of ≥3 servings per week scored 0 points.

Fluid component

The EGSNZA recommends consuming eight glasses of fluids per day, and is based on the question, 'on average, how many drinks do you have per day'. The component was a continuous scale, and scoring was determined by the number of glasses consumed. For this component, 8 glasses per day scored of 10 points, 7 glasses per day scored 8.75 points, 6 glasses per day scored 7.5 points, 5 glasses per day scored 6.25 points, 4 glasses per days scored 5 points, 3 glasses per day scored 3.75 points, 2 glasses per day scored 2.5 points, 1 glass per day scored 1.25 points, and 0 drinks scored 0 points.

Proportion of water component

This component was chosen as the revised guidelines advocates choosing water over other beverages. It is based on frequency questions on 24 different beverages including water (e.g. tea, juice). The proportion of water consumption was relative to the total amount of fluids consumed each day. Scoring ranged from 0, 2.5, and 5 points. For this component, 37.5% to 50% of water consumed scored 5 points, 25% to 37.49% of water consumed scored 2.5 points, and 0% to 24.99% of water consumed scored 0 points. The scoring and cut-off points used for this component as similar to those found in McNaughton et al (McNaughton et al., 2008).

Alcohol component

Alcohol intake was used as a component as this is a key guideline statement, as the recommendation for women in the EGSNZA is to have no more than 10 standard drinks per week. It was based on frequency questions of 11 different alcoholic drinks (e.g. beer, wine). Responses were converted to servings per week and combined to provide a total number. The component was a continuous scale, and scoring was determined by the number of servings based on the guidelines. For this component, 10 or more alcoholic drinks scored 0 points, 9 alcoholic drinks scored 0.5 points, 8 alcoholic drinks scored 1 points, 7 alcoholic drinks scored 1.5 points, 6 alcoholic drinks scored 2 points, 5 alcoholic drinks scored 2.5 points, 4 alcoholic drinks scored 3 points, 3 alcoholic drinks scored 3.5 points, 2 alcoholic drinks scored 4 points, 1 alcoholic drink scored 4.5 points, and 0 alcoholic drinks scored 5 points.

3.9 Data handling and data analysis

3.9.1 NZWFFQ – Conversion to NZW-HDI score

Dietary information from the NZWFFQ was used to develop the NZW-HDI. Relevant data from the NZWFFQ was exported from SurveyMonkey into an Excel spreadsheet. Exported data was checked to ensure there was no missing information, and that participant ID numbers corresponded to the FR completed. Only NZWFFQ data matched with complete food records were used in this study. Data extracted from the NZWFFQ included participant responses to the summary questions and frequency questions, which was grouped into the NZW-HDI components. Refer to Appendix E for decisions and assumptions made when converting NZWFFQ data into the NZW-HDI score. Using the criteria for the NZW-HDI components, dietary data from the NZWFFQ was converted to average intake values. To illustrate, the combined component (1) legumes, nuts, and seeds and (2) red meat, poultry, fish and seafood, and eggs was based on four different summary questions (e.g. on average, how many servings of chicken do you eat per week). To calculate the number of servings consumed for this component, servings per week for each question were converted to daily equivalents, then combined to produce a total number (e.g. 7 servings/wk = 1 serving/day). Data from the NZWFFQ was converted to scores according to the NZW-HDI criteria described in section 3.8.3. Hence, a score of 0, 5, or 10 was given to depending on the number of servings consumed.

3.9.2 Food records – Conversion to NZW-HDI score

In order to assess relative validity of the NZW-HDI, the four-day weighed food records completed by participants were converted into NZW-HDI individual components to derive a total score. The same assumptions and decisions used in Appendix E were used for the conversion of the FR to the NZW-HDI score. Additional assumptions made from the FR for each index component are shown in Appendix F. Serving sizes for each component were obtained from the NZWFFQ (e.g. 1 serving of fruit = ½ cup). For each food within the corresponding index component (e.g. fruit – banana, apple, and orange) the weight in grams from each food item consumed were converted into volume (cups) over the four days. An average intake was obtained for each food item. This was considered the most appropriate method for analysis. Refer to Appendix G for conversion factors used for the NZW-HDI derived from the FR. Next, all food items were combined to make up individual components. From this, a total score of the NZW-HDI was produced from the FR data.

3.9.3 Food records – Conversion to nutrients

To assess construct validity, food records were analysed for nutrient intakes. Food records were entered manually into Foodworks (version 7, 2013, Xyris Software, Queensland) by three MSc students. Foodworks is a nutrition software program used to analyse diets, recipes and nutrients. It also provides an in-depth analysis of energy, macro- and micronutrient intakes. The New Zealand – Diet and Recipe Analysis (abridged) database was selected for food record entry, as it is a complete dataset without any missing nutrient values. Throughout data entry of the food records, two NZ registered dietitians (NZRD) supervised the process. Once all the food records had been entered, an external MSc student who did not participate in data entry counter-checked 15% of the food records for accuracy purposes.

3.10 Statistical analysis

For statistical analysis, data was entered into IBM SPSS statistics package version 22.0 (IBM corporation, New York, USA) was used. The components were tested for normality using Kolmogorov-Smirnov and Shapiro Wilk tests, and for homogeneity using the Levene's test. Normality was also visually checked using histograms, box plot, de-trended plot and Q-Q normality plot. Where data was not normally distributed, a log transformation was conducted in order to obtain normality. Descriptive statistics were used for participant characteristics, NZW-HDI scores and index components, and food record data (n=110). Mean ± standard deviation (SD) was used to describe parametric data, whereas non-parametric data was reported as median [25^{th}, 75^{th} percentiles]. Categorical data was described using frequency statistics.

Relative validity

The relative validity of HDI scores derived from the NZWFFQ was compared with HDI scores derived from the FR. The relative validity of both the total HDI score and sub-scores for each individual component were investigated using a range of statistical tests. For all tests, a *P*-value of less than 0.05 was considered statistically significant.

Paired t-tests and Pearson's correlation coefficients were used to investigate differences and associations respectively between HDI scores derived from the NZWFFQ versus the FR. Based on recommendations by Hopkins, Marshall, Batterham, and Hanin (2009), the following descriptors for correlation coefficients were used: 0.9 - 1 almost perfect; 0.7 - 0.9 very high; 0.5 - 0.7 high; 0.3 - 0.5 moderate; 0.1 - 0.3 low and 0-0.1 insubstantial.

Cross classification was performed using tertile distribution of the NZW-HDI sub-scores and total score for the HDI derived from the NZWFFQ and from the FR. This was used to determine whether the dietary assessment methods classified participants correctly into the same tertile or misclassified participants into the opposite tertile. Correct classification into the same tertile should occur for >50% participants, and misclassification should occur for <10% of participants (Masson et al., 2003). Finally, the level of agreement between the two dietary methods was further investigated using the kappa (κ) statistic. The formula used to determine the κ-statistic was: $\kappa = Pr(a) - Pr(e) / 1 - Pr(e)$ where Pr(a) is the relative observed agreement among the NZW-HDI derived from the NZWFFQ versus the FR, and Pr(e) is hypothetical probability of chance agreement (Altman, 1991). If the two dietary methods completely agree then $\kappa = 1$, and if there's no agreement between the two methods other than that expected by chance (Pr(e)) then $\kappa = 0$. Using the formula, correct classification into the same third by each dietary assessment was given a factor of 1; 0.5 for adjacent thirds; and zero for opposite thirds (Altman, 1991). Values of $\kappa > 0.80$ indicate very good agreement, between 0.61 and 0.80 good agreement, 0.41-0.60 moderate agreement, 0.21-0.40 fair agreement, and <0.20 poor agreement (Masson et al., 2003).

Construct validity

Construct validity was assessed by comparing the NZW-HDI total score and sub-scores with energy and nutrient intakes derived from the FR. Dietary intakes of participants included in the analysis were: energy, total fat, saturated fat, protein, carbohydrates, sugar, dietary fibre, vitamin C, beta-carotene, folate, sodium, iron, calcium, and alcohol. Spearman's rank correlation coefficient was used to compare the NZW-HDI total score and sub-scores with nutrient intakes.

In addition, construct validity of the NZW-HDI was assessed by comparing the NZW-HDI scores with energy and nutrient intakes from the food record using a linear trend analysis. This was tested by including the tertile distribution of the NZW-HDI total score as the categorical variable, and the *P*-value for the linear trend was calculated using polynomial contrast for continuous variables (e.g. nutrient intakes).

4. Results

This research study aimed to develop the New Zealand Women's Healthy Diet Index (NZW-HDI), a tool used to measure overall diet quality and adherence to the Eating and Activity Guidelines for New Zealand Adults, and validate the index by comparing the NZW-HDI against a four-day weighed food record (FR), as well as to nutrient intakes derived from the FR. It was conducted with a subsample of women participating in the Women's EXPLORE study at Massey University. This chapter describes the results of the study. The characteristics of the participants are presented first, followed by a breakdown of participants' results for the NZW-HDI total score and sub-scores for individual components. Lastly, relative and construct validity of the NZW-HDI are investigated, which includes comparisons between: the NZW-HDI derived from the New Zealand Women's Food Frequency Questionnaire (NZWFFQ) and the NZW-HDI derived from the FR total score (and individual component sub-scores), as well as the NZW-HDI score compared with nutrient intakes derived from the FR .

4.1 Participant characteristics

This analysis is based on data from 111 young women who participated in the EXPLORE study, who completed both the New Zealand Women's Food Frequency Questionnaire (NZWFFQ) and a four day weighed food record (FR). One NZWFFQ had missing responses, therefore this data was excluded. In total, 110 participants were included in the final validity analysis. Demographic characteristics of the sample are presented in Table 4.1. The mean age of participants was 32.4 years, and the majority were of New Zealand European ethnicity (80.9%). The median body mass index (BMI) of the women was 23 kg/m^2 (66.4%), and most of the participants were within a normal BMI range.

Table 4.1 Participant characteristics of a subsample of women from the EXPLORE study (n=110)

Characteristics	**n (%)**
Age (years)	32.41 ± 7.56[1]
Ethnicity	
New Zealand European	89 (80.9)
Māori	13 (11.3)
Pacific	8 (7.3)
BMI (kg/m^2)[2]	23 (21.1, 26.1)
Normal BMI (18.5 – 24.99 kg/m^2)*	73 (66.4)
Overweight & obese (BMI ≥ 25 kg/m^2)*	37 (33.6)

BMI, body mass index

[1]Mean ± SD used for normally distributed data

[2]Median (25th, 75th percentiles) used for not normally distributed data

Note: BMI cut-off point for all ethnic groups: Ministry of Health (2008)

4.2 New Zealand Womens' Healthy Diet Index scores

4.2.1 NZW-HDI total score

The mean NZW-HDI score derived from the NZWFFQ of participants was 76.7 ± 0.9, and ranged from 53 to 96. Out of the possible of score of 115, a higher NZW-HDI score reflected a diet more consistent with dietary guidelines. The distribution of participants stratified by NZW-HDI scores are shown in Table 4.2. Few participants scored too high or too low, with nearly one third of participants scoring between 80 and 89 (32.6%). This indicates that participants had moderate adherence to the EAGNZA.

Table 4.2 Distribution of participants by NZW-HDI scores (n=110)

NZW-HDI score	n (%)[1]
<49	0
50-59	6.5
60-69	19.6
70-79	31.5
80-89	32.6
>90	9.8
Mean ± SD	76.7 ± 0.9

NZW-HDI, New Zealand Women's Healthy Diet Index

[1]Data displayed as proportion of participants distributed in each scoring category

4.2.2 Scores of NZW-HDI components

Table 4.3 shows the breakdown of the frequency of participants in each scoring category. Overall, there was a range of scores for each component. To illustrate, it can be observed that the majority (62.8%) of participants consumed two or more servings of fruit per day, and therefore received the maximum possible score of 10. For the following components, total adherence (maximum score) to the dietary guidelines was achieved by the majority of participants: the combined component (1) legumes, nuts and seeds or (2) fish and seafood, eggs, poultry, and red meat (92.7%), vegetable consumption (81.4%); grams of red meat consumed (69.1%); proportion of whole grains relative to total amount of grains consumed (65.5%); fruit consumption (62.8%); takeaway consumption (54.5%); and type of milk purchased (58.4%). These higher sub-scores would have contributed to an increased total score. Less participants met the following components of the NZW-HDI: total amount of grains consumed (1.8%), consumption of high sugar foods (3.6%), vegetable variety (10.0%), dairy consumption (10.9%), alcohol consumption (23.0%), fruit variety (26.4%), fluid consumption (29.1%), proportion of water relative to total amount of fluids (33.6%), salt added to food or used in cooking (35.4%), and trimming of fat off meat and skin off chicken (46.2%). Poor adherence to these guidelines contributed to a decreased total score. In addition, correlations between the total score and the individual components suggest that fruit consumption, vegetable consumption, grain

consumption, milk and milk products consumption, amount of red meat consumed, and fluids consumed had more influence on the total NZW-HDI score relative to the other NZW-HDI components.

Table 4.3 Frequency of participants in each scoring category for NZW-HDI component sub-scores, and correlation of index components with total score (n=110)

NZW-HDI components	Criteria for scoring	NZW-HDI score	% of participants in scoring category	Correlation with NZW-HDI total score
Fruit variety: Number of coloured fruits consumed in each category (red, orange/yellow, purple/blue, green, white/brown)[1]	0 – 0.99	0	4.5	0.363*
	1 – 1.99	1	3.6	
	2 – 2.99	2	2.7	
	3 – 3.99	3	29.1	
	4 – 4.99	4	33.6	
	>5	5	26.4	
Vegetable variety: Number of coloured vegetables consumed in each category (red, orange/yellow, purple/blue, green, white/brown)[1]	0 – 0.99	0	0.9	0.135
	1 – 1.99	1	0.9	
	2 – 2.99	2	4.5	
	3 – 3.99	3	60.0	
	4 – 4.99	4	23.6	
	>5	5	10.0	
Fruit: Servings of fruit per day	0	0	7.7	0.452*
	1	5	28.2	
	>2	10	64.5	
Vegetables: Servings of vegetables per day	0	0	0.9	0.284*
	1	0.33	2.7	

NZW-HDI components		Criteria for scoring	NZW-HDI score	% of participants in scoring category	Correlation with NZW-HDI total score
		2	0.66	12.7	
		>3	0.99	83.6	
Grain foods: Servings of breads and cereals per day		0	0	5.5	0.453*
		1 – 1.99	1.66	30.0	
		2 – 2.99	3.32	0	
		3 – 3.99	4.98	29.1	
		4 – 4.99	6.64	0	
		5 – 5.99	8.31	0	
		>6	9.96	35.5	
Wholegrain foods: Proportion of wholemeal/wholegrain choices relative to total amount of total grains consumed (%)		0 - 24.99	0	0	0.095
		25 - 37.49	1.25	4.5	
		37.5 - 49.99	2.5	5.5	
		50 - 74.99	3.75	25.5	
		>75	5	64.5	
Milk and milk products: Servings of milk and milk products per day		0 – 0.99	0	28.2	0.323*
		1 – 1.99	1	11.8	
		>2	2	60.0	
(1) Legumes, nuts, seeds: Servings per day	(2) Seafood, eggs, poultry or red meat: Servings per day	(1) 0 – 0.99	0	2.7	0.173
		(1) 1 – 1.99 (2) 0.5 – 0.99	5	4.5	
		(1) >2 (2) >1	10	92.7	

NZW-HDI components	Criteria for scoring	NZW-HDI score	% of participants in scoring category	Correlation with NZW-HDI total score
Type of milk purchased	Whole milk	0	27.4	
	Both types of milk	2.5	11.5	0.124
	Low fat milk	5	58.4	
Amount of red meat consumed	<500 g	0	30.9	0.320*
	>500 g	5	69.1	
Trimming of fat from meat, removal of skin from chicken	Never/Not applicable	0	15.5	0.108
	Occasionally	2.5	13.6	
	Often/Always	5	70.9	
Salt: Salt used in cooking, salt used at the table	Never/Rarely/Not applicable	0	33.6	0.154
	Sometimes	2.5	30.0	
	Always	5	36.4	
Takeaways: Takeaway consumption per week	0 – 0.99	0	7.3	0.074
	1 – 1.99	2.5	38.2	
	>2	5	54.5	
High sugar food (e.g. chocolate, cakes, biscuits): Number of servings from each category per week	0 – 0.99	0	3.6	0.086
	1 – 1.99	2.5	8.2	
	>2	5	88.2	

NZW-HDI components	Criteria for scoring	NZW-HDI score	% of participants in scoring category	Correlation with NZW-HDI total score
Fluids: Frequency of consumption of beverages	0 – 0.99	0	0.9	
	1 – 1.99	1.25	0	
	2 – 2.99	2.5	6.4	0.356*
	3 – 3.99	3.75	0	
	4 – 4.99	5	24.5	
	5 – 5.99	6.25	0	
	6 – 6.99	7.5	0	
	7- 7.99	8.75	39.1	
	>8	10	29.1	
Fluids: Proportion of water consumed relative to total beverages (%)	0 - 12.49	0	1.8	0.183*
	12.5 - 24.99	1.25	15.5	
	25 - 37.49	2.5	29.1	
	37.5 - 49.99	3.75	19.1	
	>50	5	34.5	
Alcohol: Number of standard drinks per week	0 – 0.99	0	7.3	0.153
	1 – 1.99	1	0.9	
	2 – 2.99	1.5	5.5	
	3 – 3.99	2	1.8	
	4 – 4.99	2.5	7.3	
	5 – 5.99	5	10	
	6 – 6.99	3	4.5	

NZW-HDI components	Criteria for scoring	NZW-HDI score	% of participants in scoring category	Correlation with NZW-HDI total score
Alcohol: Number of standard drinks per week	7- 7.99	3.5	10.9	
	8 – 8.99	4	14.5	
	9 – 9.99	4.5	13.6	
	>10	5	23.6	

Note: (1) legumes, nuts, seeds and (2) fish and seafood, eggs, poultry or red meat are a combined NZW-HDI component

*Correlation is significant at the 0.05 level (two-tailed)

4.3 Relative validity of the NZW-HDI

Total score

The validity and agreement between NZW-HDI scores derived from the NZWFFQ relative to those from the FR were compared using paired t-tests, Pearson correlations, cross-classification and weighted κ –statistic (see Table's 4.4 and 4.5).The NZWFFQ derived NZW-HDI mean total score was 76.7 ± 9.8, and the FR derived NZW-HDI was 75.2 ± 11.1. A significant difference between the two scores was found using paired t-tests, however the difference in the total scores was only 1.5 points. Pearson's correlation coefficient showed there was a significant low correlation between the total scores for the two methods (r = 0.29; *P* = 0.002). In addition, cross classification showed 50% of participants were classified into the same tertile (50% recommended) and 16% were misclassified into opposite tertiles (<10% recommended). The weighted κ-statistic showed that the HDI derived from the NZWFFQ and FR had fair agreement (κ = 0.244).

Individual index components

Paired t-tests showed that individual component sub-scores from the NZWFFQ derived NZW-HDI were significantly higher than scores FR derived NZW-HDI for fruit variety, fruit consumption, vegetable consumption, grain consumption, proportion of wholemeal/wholegrain choices relative to total grains consumed, the consumption of the combined component (1) legumes, nuts, seeds or (2) seafood, eggs, poultry or red meat and fluid consumption ($P < 0.05$), In contrast, scores for

consumption of milk and milk products, weekly red meat consumption, consumption of foods high in sugar, water consumption, and salt added to food or used in cooking were higher for the FR derived NZW-HDI (see Table 4.3). Significant moderate correlations (r = 0.3-0.5) were observed between individual component sub-scores from the NZWFFQ derived NZW-HDI and the FR derived NZW-HDI for fruit variety, fruit consumption, fluid consumption and alcohol intake ($P < 0.01$). A significant positive high correlation was observed for grain consumption ($r = 0.557$; $P < 0.01$) and significant positive correlations (all low) were observed for vegetable variety, type of milk purchased and water consumption. The following individual component sub-scores met Masson et al. (2003) criteria for correct classification into the same tertile of more than 50%: fruit consumption (54%), grain consumption (57%), consumption of milk and milk products (54%), the consumption of the combined component (1) legumes, nuts, seeds or (2) seafood, eggs, poultry or red meat (83%), weekly consumption of red meat (71%), type of milk purchased (53%), salt added to food or used in cooking (53%), and fluid (58%), water (56%) and alcohol (62%) consumption. Gross misclassification should occur for <10% of participants (Masson et al., 2003). The following individual component sub-scores met this criteria: fruit variety (5%), vegetable consumption (8%), grain consumption (6%), combined consumption of 1) legumes, nuts, seeds or (2) seafood, eggs, poultry or red meat (0%), and weekly consumption of red meat (0%), In conjunction with the cross-classification analysis, the weighted κ-statistic showed the index components between the two dietary methods used to derive the HDI to range from poor to moderate agreement ($\kappa = 0.013 – 0.542$) (see Table 4.5)

Table 4.4 Comparison of sub-scores for each component and total score from NZWFFQ-derived NZW-HDI to FR-derived NZW-HDI (n=110)

NZW-HDI components	Mean intake for components – NZW-HDI[1]	Mean intake for components – FR[1]	Difference of mean intake between NZW-HDI and FR	NZW-HDI score	FR score	Difference between NZW-HDI score and FR score	Paired t-test (*P* value)[2]
Fruit variety: Number of coloured fruits in each category (red, orange/yellow, purple/blue, green, white/brown)	3.6 ± 1.3	2.5 ± 1.2	0.9	3.6 ± 1.3	2.5 ± 1.2	1.1	0.003
Vegetable variety: Number of coloured vegetables in each category (red, orange/yellow, purple/blue, green, white/brown)	3.3 ± 0.8	3.6 ± 0.9	-0.3	3.3 ± 0.8	3.6 ± 0.9	-0.3	0.052
Fruit: Servings of fruit per day	1.9 ± 0.9	1.5 ± 1.2	0.4	7.9 ± 3.1	5.0 ± 4.1	2.9	<0.001
Vegetables: Servings of vegetables per day	3.3 ± 0.9	2.9 ± 1.8	0.4	9.2 ± 1.8	7.2 ± 3.2	2	<0.001
Grain foods: Servings of breads and cereals per day	2.7 ± 1.5	2.8 ± 1.4	-0.1	5.0 ± 3.8	3.5 ± 2.2	2.5	<0.001
Wholegrain foods: Proportion of wholemeal/wholegrain choices relative to total amount of breads and cereals	75.9 ± 21.2	60.1 ± 28.5	15.8	4.4 ± 1.0	3.7 ± 1.3	1.7	<0.001

NZW-HDI components	Mean intake for components – NZW-HDI[1]	Mean intake for components – FR[1]	Difference of mean intake between NZW-HDI and FR	NZW-HDI score	FR score	Difference between NZW-HDI score and FR score	Paired t-test (*P* value)[2]
Milk and milk products: servings of milk and milk products per day	1.1 ± 0.8	1.6 ± 3.9	-1.5	3.0 ± 3.4	7.1 ± 3.6	-4.1	<0.001
(1) Legumes, nuts, seeds OR (2) Seafood, eggs, poultry or red meat: Servings per day	1.4 ± 0.7	1.6 ± 1.0	-0.2	9.5 ± 1.9	8.6 ± 2.7	0.9	0.003
Red meat: Amount of red meat consumed per week (g)	346.9 ± 240.2	179.8 ± 253.5	167.1	3.4 ± 2.3	4.2 ± 1.5	-0.8	0.003
Type of milk purchased	-	-	-	3.3 ± 2.2	3.4 ± 2.2	-0.1	0.727
Trimming of fat from meat, removal of skin from chicken	-	-	-	3.5 ± 1.6	3.3 ± 2.2	-0.2	0.056
Salt: Salt used in cooking, salt used at the table	-	-	-	2.6 ± 2.1	3.8 ± 1.4	-1.2	<0.001
Takeaways: Takeaway consumption per week	1.3 ± 0.7	1.8 ± 2.1	-0.5	3.7 ± 1.6	2.9 ± 2.1	0.8	0.002
High sugar food (e.g. chocolate, cakes, biscuits): Number of servings from each category per week	8.5 ± 6.8	4.8 ± 4.8	3.7	0.4 ± 1.1	1.7 ± 2.3	-1.3	<0.001

NZW-HDI components	Mean intake for components – NZW-HDI[1]	Mean intake for components – FR[1]	Difference of mean intake between NZW-HDI and FR	NZW-HDI score	FR score	Difference between NZW-HDI score and FR score	Paired t-test (*P* value)[2]
Fluids: Frequency of consumption of beverages per day	6.9 ± 2.5	6.2 ± 3.1	0.7	6.6 ± 2.8	3.4 ± 1.4	3.2	<0.001
Water: Proportion of water consumed relative to total beverages per day	45.4 ± 21.6	56.2 ± 26.8	-10.8	3.4 ± 1.4	4.0 ± 1.6	-0.6	<0.001
Alcohol: Number of standard drinks per week	4.2 ± 4.9	4.1 ± 6.6	-0.1	3.4 ± 1.5	3.6 ±1.7	-0.2	0.294
Total score	-	-	-	76.7 ± 9.8	75.2 ± 11.1	1.5	0.004

FR, Food record; NZWFFQ, New Zealand Women's NZW-HDI, New Zealand Women's Healthy Diet Index.

Note. Mean intakes for the following components could not be calculated: type of milk purchased, trimming of fat from meat, removal of skin from chicken, salt used in cooking and at the table

[1]Values represent mean ± SD

[2]Paired t-test between NZW-FFQ derived NZW-HDI and FR derived NZW-HDI score

Table 4.5 Pearson correlation coefficients and agreement between NZWFFQ-derived NZW-HDI to FR-derived NZW-HDI (n=110)

NZW-HDI components	NZW-HDI score[1]	FR score[1]	Correlation coefficients (*r*)	Correlation (*P*-value)	% CC	% GM	Weighted κ-statistic
Fruit variety: Number of coloured fruits in each category (red, orange/yellow, purple/blue, green, white/brown)	3.6 ± 1.3	2.5 ± 1.2	0.310	0.001	39	5	0.132
Vegetable variety: Number of coloured vegetables in each category (red, orange/yellow, purple/blue, green, white/brown)	3.3 ± 0.8	3.6 ± 0.9	0.215	0.024	37	10	0.051
Fruit: Servings of fruit per day	7.9 ± 3.1	5.0 ± 4.1	0.392	<0.001	54	20	0.291
Vegetables: Servings of vegetables per day	9.2 ± 1.8	7.2 ± 3.2	0.032	0.741	29	8	0.013
Grain foods: Servings of breads and cereals per day	5.0 ± 3.8	3.5 ± 2.2	0.557	<0.001	57	6	0.354
Wholegrain foods: Proportion of wholemeal/wholegrain choices relative to total amount of breads and cereals	4.4 ± 1.0	3.7 ± 1.3	0.126	0.190	44	31	0.082
Milk and milk products: servings of milk and milk products per day	3.0 ± 3.4	7.1 ± 3.6	0.028	0.773	54	52	0.045

NZW-HDI components	NZW-HDI score[1]	FR score[1]	Correlation coefficients (*r*)	Correlation (*P*-value)	% CC	% GM	Weighted κ-statistic
(1) Legumes, nuts, seeds OR (2) Seafood, eggs, poultry or red meat: Servings per day	9.5 ± 1.9	8.6 ± 2.7	0.112	0.246	83	0	0.073
Red meat: Amount of red meat consumed per week (g)	3.4 ± 2.3	4.2 ± 1.5	0.111	0.249	71	0	0.135
Type of milk purchased	3.3 ± 2.2	3.4 ± 2.2	0.237	0.013	53	35	0.134
Trimming of fat from meat, removal of skin from chicken	3.5 ± 1.6	3.3 ± 2.2	0.052	0.587	14	18	0.045
Salt: Salt used in cooking, salt used at the table	2.6 ± 2.1	3.8 ± 1.4	-0.126	0.190	53	44	0.542
Takeaways: Takeaway consumption per week	3.7 ± 1.6	2.9 ± 2.1	0.133	0.166	47	34	0.091
High sugar food (e.g. chocolate, cakes, biscuits): Number of servings from each category per week	0.4 ± 1.1	1.7 ± 2.3	0.169	0.077	7	40	0.047
Fluids: Frequency of consumption of beverages per day	6.6 ± 2.8	3.4 ± 1.4	0.422	<0.001	58	10	0.362

NZW-HDI components	NZW-HDI score[1]	FR score[1]	Correlation coefficients (*r*)	Correlation (*P*-value)	% CC	% GM	Weighted κ-statistic
Water: Proportion of water consumed relative to total beverages per day	3.4 ± 1.4	4.0 ± 1.6	0.280	0.003	56	33	0.253
Alcohol: Number of standard drinks per week	3.4 ± 1.5	3.6 ±1.7	0.432	<0.001	62	12	0.321
Total score: NZW-HDI	76.7 ± 9.8	75.2 ± 11.1	0.288	0.002	50	16	0.244

% CC, Percent Correctly Classified; % GM, Percent Grossly ,isclassified; FR, Food record; NZWFFQ, New Zealand Women's Food Frequency Questionnaire; NZW-HDI, New Zealand Women's Healthy Diet Index

Note: Cross classification (correctly classified: >50% in same tertile, grossly misclassified: <10% in opposite tertiles). Weighted κ-statistic (κ >0.80 indicate very good agreement, between 0.61 and 0.80 good agreement, between 0.41 and 0.60 moderate agreement, between 0.21 and 0.40 fair agreement, and <0.20 poor agreement)

[1]Values represent mean ± SD

4.4 Construct validity

Table 4.6 summarises the correlations between the NZW-HDI total score and components, with energy and nutrient intakes derived from the FR. The NZW-HDI total score was positively related to dietary fibre, vitamin C, folate, and calcium intakes (0.227, 0.214, 0.286, and 0.277 respectively; all $P < 0.05$), and inversely related to saturated fat (-0.318*; P* < 0.05). In addition, based on correlation coefficient descriptors, the majority of NZW-HDI individual components derived from the NZW-FFQ had low to moderate correlations with nutrient intakes from the FR ($r = 0.1 – 0.3$). Fruit variety correlated with energy, sugar, dietary fibre and vitamin C; fruit consumption correlated with energy, total carbohydrates, sugar, dietary fibre, vitamin C, and folate; total grains consumed correlated with dietary fibre, folate and sodium; milk and milk product consumption correlated with energy and calcium; and the amount of red meat consumed correlated with energy.

Table 4.6 Correlations between the NZW-HDI (total score and individual components) based on the NZWFFQ and energy and nutrient intakes derived from the FR, significant at the 5% level (n=110)

	NZW-HDI total score	Fruit variety	Vegetable variety	Fruit	Vegetables	Grains	Proportion of whole grains	Dairy	Legumes or meat	Amount of red meat	Type of milk	Fat off meat	Salt use	Takeaway	High sugar foods	Fluids	Proportion of water	Alcohol
Energy (kJ)	0.006	0.292*		0.452*	0.284*	0.453*		0.323*		0.320*								
Protein (g)	0.072																	
Carbohydrates (g)	0.053			0.191*														
Sugar (g)	0.120	0.194*		0.239*														
Total fat (g)	0.035																	
Saturated fat (g)	-0.318*																	
Dietary fibre (g)	0.227*	0.310*		0.258*		0.244*												

	NZW-HDI total score	Fruit variety	Vegetable variety	Fruit	Vegetables	Grains	Proportion of whole grains	Dairy	Legumes or meat	Amount of red meat	Type of milk	Fat off meat	Salt use	Takeaway	High sugar foods	Fluids	Proportion of water	Alcohol
Vitamin C (mg)	0.214*	0.291*		0.312*														
Beta-carotene (µg)	0.084																	
Folate (µg)	0.286*			0.193*		0.314*												
Sodium (mg)	0.057					0.214*												
Calcium (mg)	0.277*							0.331*										
Iron (mg)	0.058																	
Alcohol (g)	-0.236*																	

FR, food record; NZWFFQ, New Zealand Women's Food Frequency Questionnaire; NZW-HDI, New Zealand Women's Healthy Diet Index.

Finally relationships between NZW-HDI scores and nutrient intakes were investigated by comparing nutrient intakes across tertiles of the NZW-HDI score. Those in the highest tertile had higher intakes of vitamin C and total folate as shown in Table 4.7. While not significant, a positive trend was shown for fibre, beta-carotene, calcium, and iron moving from the lowest to highest tertile of the NZW-HDI score, and a negative trend was seen for total fat and alcohol.

Table 4.7 Dietary intakes derived from FR by tertiles of the NZW-HDI (n=110)

Nutrients	**Tertiles of NZW-HDI score**[1]			***P*-value**
	1	**2**	**3**	
Energy (kJ)	7694 ± 1401	7970 ± 1369	7740 ± 2294.7	0.563
Protein (g)	80 ± 16.2	88.4 ± 26.7	87.7 ± 30.3	0.136
Total fat (g)	77 ± 25.4	74.7 ± 20.3	73.5 ± 23.6	0.884
Saturated fat (g)	29 ± 12.4	26.6 ± 7.9	26.9 ± 11.1	0.456
Carbohydrates (g)	186.9 ± 40.0	208.6 ± 48.4	206.0 ± 76.6	0.205
Sugar (g)	91.4 ± 32.2	98.2 ± 26.9	91.7 ± 32.4	0.831
Dietary fibre (g)	25.0 ± 23.4	26.7 ± 7.3	28.0 ± 15.4	0.299
Vitamin C (mg)	84.3 ± 48.5	100.2 ± 51.3	112.1 ± 57.7	0.030*
Beta-carotene (µg)	3198.1 ± 2158.4	3469.2 ± 2091.5	3750.7 ± 2735.5	0.413
Total folate (µg)	353.2 ± 137.2	411.8 ± 145.7	456.5 ± 206.7	0.011*
Sodium (mg)	2280.8 ± 811.0	2686.6 ± 1569.8	2464.8 ± 786.2	0.692
Calcium (mg)	899.5 ± 291.0	921.4 ± 242.3	997.5 ± 463.7	0.365
Iron (mg)	12.3 ± 3.2	13.3 ± 3.9	13.7 ± 6.4	0.191
Alcohol (g)	13.5 ± 15.5	8.4 ± 9.5	3.9 ± 6.1	0.073

FR, food record; NZW-HDI, New Zealand Women's Healthy Diet Index

[1] Values are mean ± SD

[2] Correlation is significant at $P < 0.05$

5. Discussion

To our knowledge, this is the first study in New Zealand (NZ) that has used a diet quality index to measure the adherence of young women to national dietary guidelines. Both the relative and construct validity of the New Zealand Women's Healthy Diet Index (NZW-HDI), derived from a food frequency questionnaire, were assessed using another dietary assessment method (a four day food record). The NZW-HDI was able to assess the adherence to the dietary guidelines, and there was reasonable validity and agreement between the NZW-HDI and FR total scores. In terms of construct validity, the NZW-HDI total score was positively associated with dietary fibre, vitamin C, folate, and calcium intakes, and inversely related to saturated fat.

5.1 Adherence to the dietary guidelines

The NZW-HDI was able to adequately reflect adherence to the dietary guidelines that it was based upon. This work shows that adherence to the Eating and Activity Guidelines for New Zealand Adults (EAGNZA) is moderate in this study population. Overall, there was variation in the dietary guidelines met. Poor adherence to the EAGNZA was found particularly for total amount of grains consumed (1.8%), consumption of high sugar foods (3.6%), vegetable variety (10.0%), milk and milk product consumption (10.9%). Younger women have been shown to consume less grain foods (e.g. breads and cereals) than men, are less likely to meet the recommended number of servings for fruit and vegetables, and have a lower calcium intake due to inadequate milk and milk product consumption. In addition, sugar-sweetened beverages, chocolate and confectionary are highly consumed by NZ adults (University of Otago and Ministry of Health, 2011b).

5.2 Relative validity

The relative validity of the developed NZW-HDI was determined by comparing the total scores of the NZWFFQ derived NZW-HDI to the FR derived NZW-HDI. The total scores NZW-HDI derived from the two dietary methods were very similar (76.7 ± 9.8, NZWFFQ derived NZW-HDI; 75.2 ± 11.1, FR derived NZW-HDI). Paired t-tests showed a significant difference between the two total scores *(P* < 0.05) despite only a slight difference of 1.5 points between the two methods.

There was a small, but significant correlation coefficient between the NZWFFQ versus the FR derived NZW-HDI of 0.28 *(P* < 0.05). Limited research has been undertaken to determine the relative validity of DQIs when compared to other dietary assessment methods. In the New Zealand Diet Quality Index for Adolescents (NZDQI-A), correlation coefficients were 0.39 (Wong et al., 2013). In this study by Wong et al. (2013), relative validity was determined based on previous correlation coefficients from other studies that compare diet quality scores from two dietary methods. Based on the

research, observed correlations ranged from 0.20 to 0.66 (Bountziouka, Tzavelas, Polychronopoulos, Constantinidis, & Panagiotakos, 2011; Newby et al., 2003; Torheim et al., 2003). The observed correlation found fell within this range, therefore can be deemed an acceptable correlation coefficient for DQIs. Moreover, cross classification showed 50% of participants were correctly classified into the same third by the two dietary methods. However, 16% of participants were classified into opposite thirds, indicating the possible impact of measurement error (Masson et al., 2003). This is comparable to the cross-classification analysis for the NZDQI-A, in which 50% of participants were classified into the same thirds while 10% were grossly misclassified into opposite thirds (Wong et al., 2013). When the weighted κ-statistic was calculated, it was found that the two dietary methods had fair agreement in ranking the total NZW-HDI score (κ =0.244). This study is the first that has used the weighted κ-statistic as a summary measure of cross-classification for validating DQIs.

While not the focus of this research, comparisons between individual components of the NZW-HDI derived from the NZWFFQ versus the FR were compared. The correlation coefficients for the individual components ranged from -0.126 (salt use) (not significant) to 0.557 (grain foods consumed) *(P* < 0.05), and were moderate on average. Cross classification showed 50% of participants were classified into the same tertile (50% recommended) the weighted κ-statistic showed sub-scores of index components between the two dietary methods to have poor to moderate agreement (κ = 0.013 – 0.542). It has been suggested that poor agreement for individual components may be attributed to small sample size or narrow cut-off points, as cross-classification will group participants with similar scores into different thirds if they are close to the cut-off point (Masson et al., 2003; Wong et al., 2013). The misclassification of only a few participants can make a significant impact to the percentages (Masson et al., 2003). Nevertheless, as DQIs combine components to produce a summary measure of diet quality (Fransen & Ocke, 2008), the relative validity of individual components is less important than that of the total NZ-HDI score.

5.3 Construct validity

To determine the construct validity of the index as a measure of diet quality, average nutrient intakes derived from the FR were compared across tertiles of the NZW-HDI total score. Higher NZW-HDI scores were associated with an increased intake of vitamin C and folate across tertiles ($P < 0.05$). Although not significant, a positive trend was shown for fibre, beta-carotene, calcium, and iron moving from the lowest to highest tertile of the NZW-HDI score, and a negative trend was seen for total fat and alcohol. These results show that the higher NZW-HDI total scores can reflect better diet quality. These trends are consistent with other studies; in which higher diet quality scores are

associated with more favourable nutrient intakes (Fogli-Cawley et al., 2006; Stookey et al., 2000; Wong et al., 2013).

In addition, correlations between NZW-HDI total score and nutrient intakes derived from the FR were examined. Significant positive correlations were found for dietary fibre (0.227), vitamin C (0.214), folate (0.286), and calcium (0.277) intakes, and negative correlations were found with intakes of saturated fat (-0.318) and alcohol (-0.236). These results indicate that the NZW-HDI reflects the intake of a variety of nutrients known to be either beneficial or detrimental to health outcomes. These results are comparable to a larger validation study (n=6542), that used an FFQ as a reference method to validate a Diet Quality Score for fibre (0.34), vitamin C (0.48), calcium (0.13), and saturated fat (-0.41) (Toft et al., 2007).

In this study, the majority of nutrient intakes had a small to medium correlation with NZW-HDI sub-score components (r= 0.1 – 0.3) and results observed were in the expected direction. To illustrate, fruit consumption correlated with fibre, vitamin C, and folate intake; milk and milk product consumption correlated with calcium intake, and grain consumption correlated with dietary fibre, sodium, and folate intake.

5.4 Methodological issues associated with the development and validation of the NZW-HDI

There are a number of methodological considerations that need to be considered in the development and validation of the NZW-HDI. These are discussed below, and focus on the development of the NZW-HDI, the validation of the NZW-HDI, and the study population.

5.4.1 Development of the NZW-HDI

5.4.1.1 Index components, cut-off points, and scoring

There are many researcher decisions involved in the development of a diet quality index. These include choices related to the selection of dietary components, grouping of food items, cut-off points and the scoring approach used. Unfortunately, for indices previously developed there is a lack of detailed information in the literature regarding the rationale behind decisions and assumptions made.

The index components of the NZW-HDI were fundamentally based on the Eating and Activity Guidelines for New Zealand Adults (EAGNZA). A qualitative check of the index components against the dietary guidelines used ensures aspects of diet quality specified in the guidelines are captured (content validity) (Guenther, Reedy, Krebs-Smith, et al., 2008). The NZW-HDI was reviewed and it

was found that all components reflected recommendations within the EAGNZA. As there are numerous diet quality indices available, it has been suggested that researchers model newly developed indices on existing DQIs (Wirt & Collins, 2009). For the NZW-HDI, a comprehensive literature review was conducted prior to development. Based on the findings, the NZW-HDI components selected were modelled on the Dietary Guideline Index developed for the Australian population by McNaughton et al (2008).

To further limit subjectivity, cut-off values were based on the dietary guidelines where possible. Cut-off points were established based on recommendations specified in the EAGNZA, such as number of servings or types of foods to consume. Instead of using dichotomous values (e.g. a score of 0 for not adhering to guidelines, and a score of 1 for adhering to guidelines) which can be a somewhat black and white approach (Bazelmans et al., 2006; Wong et al., 2013), this study used an alternative method. A minimum and maximum score was attributed to each index component, and where possible, intermediate scores were assigned proportional to intake (e.g. number of servings consumed). This was to eliminate arbitrary adjustments and also ensured each serving was recognised and contributed to the final score. For example, for individuals who ate two servings of vegetables (and not the recommended three as in the EAGNZA, this was still recognised and contributed to the final score. In some cases, however, quantitative criteria could not be used to establish cut-off points as there was no explicit recommendation in the EAGNZA. An example in the guidelines is 'choose foods low in salt', which is not quantified. In this case, cut-off points were based on previous indices such as the DGI (McNaughton et al., 2008). It has been suggested that population specific dietary guidelines should be formulated in quantitative terms, to assist in the interpretations of dietary guidelines and to reduce the amount of arbitrary decisions in the development of an index (Wong et al., 2013).

Due to the number of index components and scoring method applied, the total score was out of 115 points. Unfortunately, this meant that the diet quality score may not be as easy to interpret. It has been suggested that a maximum score of 100 that has been used in some indices provides more meaningful interpretation, as results can be expressed as percentages (Dubois et al., 2000). However, there is no reason why the score out of 115 cannot be converted to a percentage value.

Difficulty also occurred when attributing weights for components towards the total score. For index such as the main food groups (e.g. fruits, vegetables, grain foods, milk and milk products, meat and meat products), a higher weighting of 10 points was given to toward the total score. Index components such as takeaway consumption and alcohol intake contributed only 5 points to the total score. This is based on the assumption that components can be either favourable or unfavourable to

health. However, it is still unclear as to whether index components have equal or unequal effects on diet, health, and disease (Woodruff & Hanning, 2010). This method of unequal weighting is similar to those found in previous DQIs (Bazelmans et al., 2006; Lee et al., 2008).

5.4.1.2 Use of NZWFFQ data

The dietary data from the NZWFFQ was also problematic as it was not specifically developed to construct the index. As the index was developed within the boundaries of the NZWFFQ data; the types of questions on food items may have restricted the variation in dietary variety and serving intake responses. For example, the NZWFFQ data does not distinguish between whole grains and refined grains, and there were a limited number of whole grain options that could be used compared to total grain foods. Other arbitrary decisions needed to be made regarding the NZWFFQ (see Appendix 1). Overall, data from the NZWFFQ may have misclassified participants in a way which may have affected the total NZW-HDI score. It is suggested that further validation work be undertaken using an alternative dietary assessment method, for example a short questionnaire which reflects the EAGNZA.

5.4.1.3 Adjustment for energy intake

In addition, as nutrient intakes are positively correlated with energy intake, DQIs have the potential to overrate high energy diets. This may lead to participants who consume higher amounts of energy having a better chance at adhering to the dietary guidelines, and therefore receiving a higher NZW-HDI score. Some studies have taken this into account and adjusted for energy intake by using gender and age specific recommendations (Kennedy et al., 1995). However, findings from the Healthy Eating Index 2005 have shown that index components were independent of energy intake. This is because no consensus has been reached on whether adjusting for energy is necessary (Guenther, 2008). Energy adjustment was initially attempted in the NZW-HDI, but made no further differences to the nutrients across the tertiles (data not shown). For this reason, the NZW-HDI did not adjust for energy intake.

5.4.2 Validation of the NZW-HDI

5.4.2.1 Selection of a reference method

To ensure the NZW-HDI accurately reflected diet quality, dietary information obtained from the NZWFFQ was required to be validated against an independent reference method. The weighed food record was used as it has been recognised as the 'gold standard' for dietary assessment (Biro et al., 2002). The FR is a prospective method that is not memory dependent, and has less correlated errors with a FFQ when compared to a 24-hour recall (Cade et al., 2002). Of the studies that have validated

DQIs using another dietary method, only two have used a food record (Roy et al., 2015; Wong et al., 2013), and the remainder have used food frequency questionnaires (Collins et al., 2015; Newby et al., 2003; Toft et al., 2007).

In the present study, participants were asked to maintain normal eating habits during the course of completing the FR. Participants were required to complete the food record for a duration of four days, which included three week days and one weekend day. This is a favourable duration of recording days, with four to five days recommended as an 'ideal' number of days to complete food records (Stram et al., 1995). The food record does however limitations that may influence agreement between the NZWFFQ derived NZW-HDI and the FR derived NZW-HDI. The use of a FR in this instance may be associated with a higher participant burden than other dietary assessment methods (Biro et al., 2002; Thompson & Subar, 2008). Despite the provision of audio-visual and written materials that were easy to comprehend (Grandjean, 2012), it is acknowledged that misreporting may still occur due to multiple-day recording that potentially discourages completion (Biro et al., 2002; Willet, 1998).

There were also limitations in regards to the time period in which the "test" and "reference" method covered. The two dietary methods should ideally cover the same period of time, but in this study, the NZWFFQ was completed first and therefore covered a different time period the FR. This implies that both methods did not assess the same period, which may have resulted in underestimation of the relative validity of the index (Wong et al., 2013). However, research suggests that the reference method (FR) be completed following the test method (NZWFFQ), to avoid the reference method influencing the test method (Gibson, 2005).

Similarly to the NZWFFQ, many researcher decisions and assumptions were made for the NZW-HDI score derived from the FR. In order to determine serving sizes (e.g. 1 serving of fruit) from the FR data, the weight in grams from each food item consumed was converted into volume (e.g. cups) over the four days, and then an average intake was obtained. This was deemed the most appropriate method for analysis. However, for some components this was not always possible. For example, takeaway consumption is based on the amount consumed per week. As the food record was only completed for four days, this meant the average obtained may not be as accurate. In addition, for two components - trimming of fat off meat/skin off chicken, and salt use – these could not fully be captured in the food composition database, therefore raw food record data was used as well. All of these factors may have in turn affected the validity of the NZW-HDI.

5.4.2.2 Approaches to validation

Limited validation research has been conducted on diet quality indices (Guenther, Reedy, Krebs-Smith, et al., 2008; Kant, 1996; Woodruff & Hanning, 2010), particularly validating the index with an independent reference method (e.g. multiple day food record). Content validity was assessed by ensuring all dietary guidelines from the EAGNZA corresponded to components in the NZW-HDI. Both construct and relative validity were used to determine the validity of the NZW-HDI. Although there were many methodological issues surrounding the construction and validation of the index, the results suggest that the NZW-HDI is reasonably valid as a measure of diet quality and can adequately assess adherence to the EAGNZA.

Another approach used to assess relative validity of a newly developed index involves biomarkers, which are independent markers of dietary intake (Gibson, 2005). These have become widely used to overcome the inherent limitations associated with dietary assessment methods, such as misreporting (Gibson, 2005; Thompson & Subar, 2008). However, biomarkers are expensive, and the availability of biomarkers is limited to a number of nutrients (Cade et al., 2002; Gibson, 2005). Many dietary indices have used biomarkers in the validation process (Fung et al., 2005; Hann et al., 2001; Harnack et al., 2002). For example, the Healthy Eating Index was validated using plasma biomarkers, such as carotenoids, vitamin C, and folate that are markers of long term fruit and vegetable consumption (Hann et al., 2001). Further validation of the NZW-HDI against biomarkers should be completed.

Other studies have assessed construct validity by comparing diet quality index scores with demographic and health information (Fogli-Cawley et al., 2006; McNaughton et al., 2008) For example, a higher body mass index has been associated with lower diet quality scores (Hann et al., 2001; Harnack et al., 2002; Toft et al., 2007). These studies however, require larger population groups in order to find significant associations. In addition, the use of longitudinal studies as opposed to a cross-sectional study design is recommended (McNaughton et al., 2008).

5.4.2.3 Statistical methods

A range of statistical methods were used to validate the NZW-HDI including paired t-tests, correlation coefficients, cross classification, weighted kappa statistics, and linear contrast analysis. Due to the lack of agreement on the most suitable way to present results obtained from validation studies, it has been suggested that more than one statistical method be used (Cade et al., 2002). Another statistical technique that could have been utilised is the Bland and Altman method. This would measure the level of agreement between the NZWFFQ derived NZW-HDI and FR derived

NZW-HDI, and also determine if there is any bias between the two dietary methods (Bland & Altman, 1999).

5.4.3 Study population

A total of 110 women were included in the subsample. As a general rule, validation of dietary assessment methods require a sample size of 100 – 200 participants (Cade et al., 2002), therefore, this is subsample was sufficient. However, having a larger sample size would further enhance the capability of the NZW-HDI to truly represent the population of interest. The majority of eligible participants were of New Zealand European descent (80.9%). This meant that Māori (10.9%) and Pacific (6.9%) were both under-represented. However, based on the 2013 Census on culture and identity, ethnic groups in New Zealand are similar to those found in this study. The major ethnic groups in the census were European (74%), Māori (14.9%), and Pacific (7.4%) (Statistics New Zealand, 2014). In addition, most women (73%) had a normal body mass index (18.5-24.9 kg/m^2), with a median BMI of 23 kg/m^2. Unfortunately, this may not be a representative sample, as the average BMI of New Zealand women is 28 kg/m^2 (Ministry of Health, 2015a). A convenience sample was recruited for the wider Women's EXPLORE study whereby dietary information was obtained for the NZW-HDI. The initial recruitment strategy was to identify women who were interested in health. For this reason, the respondents may be more motivated and health conscious, and not representative of other New Zealand women.

In addition, all participants volunteered to be involved in the study (Black et al., 1993). Volunteers have also been shown to have different eating habits than those who do not volunteer. It has been shown that volunteers eat breakfast more regularly, and consume less takeaway foods than non-volunteers (Kim, Kim, & Hyun, 2004). These factors may have potentially introduced bias to the sub-sample of young women, and could have contributed to the right skewed distribution of the total NZW-HDI score and individual components.

5.4.4 Other methodological issues

The reproducibility of the NZW-HDI was not assessed in this study. This is because the main data collection from the wider EXPLORE study (that included the NZWFFQ) was obtained on one occasion only. It was beyond the scope of this study to have the participants complete another FFQ at a different period of time. Reproducibility (or reliability) tests whether the same response is found when using the same dietary assessment method in the same situation (Gibson, 2005). Reproducibility is not commonly performed in validation studies (Cade et al., 2002), however, some

DQIs have used repeated FFQs to assess the reproducibility of the index (Newby et al., 2003; Wong et al., 2013).

5.5 Recommendations for future research

There are a number of recommended changes that could be made to the NZW-HDI for future use in New Zealand. These include:

- Adaption of questions within the NZWFFQ to better reflect the NZW-HDI and its application to the EAGNZA. For example, for the type of milk purchased component, frequency responses in the FFQ should include low fat milk, whole milk, and both types of milk consumed
- Further refinement of the NZW-HDI scoring methods should be under taken. This includes trialling different cut-off points to see whether enhanced validity is obtained
- Development of a shorter version of the NZW-HDI to make it more convenient for health professionals to use as a dietary assessment tool or for individuals to use as an interactive dietary education tool
- The validity of the NZW-HDI should also be tested in different population groups, for example in Asian populations, males, and in children
- Other validation techniques should be undertaken to assess the relative validity of the NZW-HDI, for example, including the use of biomarkers
- The reproducibility of the NZW-HDI should be assessed by having participants complete the NZW-HDI questions on two occasions, separated by a predetermined time frame (e.g. 4-8 weeks apart)
- New and improved versions of the NZW-HDI will be able to be used in larger studies (e.g. the larger Women's EXPLORE study) to assess diet quality and associations with health and disease

5.6 Conclusion

This is the first study to develop a diet quality index for use in New Zealand women. The NZW-HDI was shown to assess the adherence of young women to the Eating and Activity Guidelines for New Zealand Adults. Based on the NZW-HDI scores derived from the NZWFFQ and FR using a range of statistical techniques, the NZW-HDI was found to have fair relative validity for assessing diet quality in women. In terms of construct validity, the NZW-HDI total score was positively associated with dietary fibre, vitamin C, folate, and calcium intakes, and inversely related to saturated fat and alcohol. Further adaptations and research should be undertaken to improve the validity of the NZW-HDI before applying its use in studies of larger population groups.

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Appendices

Appendix A. New Zealand Women's Food Frequency Questionnaire

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	4x + / day
Bread - 1 slice									

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	4x + / 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.

2. EXPLORE Study Food Frequency Questionnaire

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

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

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

***3. 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

EXPLORE Food Frequency Questionnaire

*4. 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									

*5. 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
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									

*6. 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 meat
- 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

EXPLORE Food Frequency Questionnaire

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

	Never	<1x /	1-3x /	1x /	2-3x /	4-6x /	Once /	2-3x /	4+ x /
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 /	1-3x /	1x /	2-3x /	4-6x /	Once /	2-3x /	4+ x /
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. 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

***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, 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

EXPLORE Food Frequency Questionnaire

*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 food**

	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									

EXPLORE Food Frequency Questionnaire

*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 servin

*4. How often do you usually eat poultry?

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

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

EXPLORE Food Frequency Questionnaire

*4. How often do you usually eat seafood?

/	Never	<1 x/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									

*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
Salmon, trout or eel - palm size / ½ cup									
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									

EXPLORE Food Frequency Questionnaire

***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. 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

12. Fats and Oils

＊4. 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

EXPLORE Food Frequency Questionnaire

13. 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									

14. 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

15. 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									

EXPLORE Food Frequency Questionnaire

16. 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 serving

*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

17. 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									

EXPLORE Food Frequency Questionnaire

*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									

18. 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									

19. 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

*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

***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 time
- 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									

Appendix B. Standard Operating Procedure for the New Zealand Women's Food Frequency Questionnaire

1. The questionnaires will be completed online using the computers in building 27. The two computers must first be turned on using the power button on the hard drive. You must then log in using the Explore network account, so that the computer is ready for the participants;

   Username: ********

   Password: ********

2. Once logged in please ensure that there are three questionnaire links on the desktop i.e. Food Frequency Questionnaire, Eating Habits Questionnaire, and the Eating Behaviour Questionnaire. Open up each link, ensuring there is access. If there are any issues, please ask Zara, AJ, Sara, Kathryn Beck, or PC to help. If the issue cannot be resolved, there are hardcopies for each of the questionnaires which are kept in the pink Explore questionnaire folder which is will be beside the computers at the questionnaire station. However, the hardcopy version must be a last resort as this will have to be put into surveymonkey manually by an Explore staff member at a later date, which is time consuming.

3. The next component to check is the guidelines for the weighed food record. There is a pdf on the desktop beside the questionnaire links called 'Weighed Food Record Guidelines', open this up and make sure it plays as a video. Check the sound, if there is no sound you may have to set up the headphones from the pink Explore folder. These can be plugged into the computer hard drive in the hole marked with a headphone symbol, plug in, put the earphones in your ears and check the sound again. If there are any issues, please see one of the team members listed above. If you are going to use earphones for participants, please ensure there are small steriliser wipes at the computer station. The earphones must be cleaned by the staff member managing the questionnaire station with the wipes after each participant use. This is to maintain hygiene.

4. Participants will move to the questionnaire station after completing the BP station, this BP station is very quick (3-5minutes maximum) so ensure you are prepared by this stage. The participants are offered breakfast and a hot drink once BP has been recorded, if the participant declines please escort them straight to the questionnaire station. If the participant would like breakfast and/or a hot drink, please encourage them to consume this

at the computer stations where they will begin the questionnaires (as time may be short with multiple participants on the testing days). The questionnaire station is time consuming (25-40 minutes) so it is important to get this underway as soon as possible.

5. Once the participant is seated infront of the computer, inform them that there are three questionnaires to complete, and a video to watch afterwards.

6. The first questionnaire to complete is the Food Frequency Questionnaire; open the link for the participant. Then read the first page to the participant, taking your time through the question examples, asking at the end if they have any questions.

7. Click 'next' at the bottom of the page and this will take you to the first questionnaire question which asks for the participant ID number, please insert this full number yourself i.e. 250018 and click 'next' at the bottom of the page.

8. The questionnaire is now ready for the participant to begin. Let the participant know that you will be there to answer any questions they have whilst completing it. Leave the participant and sit at the big round table behind the computer station, so that you are close enough for any possible questions, but so that you still give the participant some privacy.

9. It is important that conversation is kept to a minimum whilst participants are completing the questionnaires, they need full focus.

10. If any questions arise during this time from the participant that you are unsure of, please ask one of the team members stated above. It is important that we obtain the most accurate information possible from the questionnaires.

11. If the links (questionnaires) stop working at any time, please see a team member stated above. You may need to provide a hardcopy for the participant to complete. If so, please ensure they complete this hardcopy version from the beginning, as their questionnaire data will not be saved unless they have 100% completed it.

12. Once the participant has completed the food frequency questionnaire, please open the 'Eating habits' questionnaire for them to complete next. Again, open up link and read the initial statement(s) to the participant. Enter in their participant ID number at the top, and then remind the participant again that you are free to answer any questions they may have over this time.

13. If there are any complications/issues please contact one of the staff members stated, and provide a hardcopy version only as a last resort (to complete from question 1 to the end).

14. Once completed, open up the 'Dietary behaviours' questionnaire, entering in the participant ID again, with the instructions as above.

15. Upon completion of the third questionnaire, the participant must watch the food record video. Open this up for the participant, and provide cleaned earphones if required.

16. Once this is finished, close the video and escort the participant to the large round table for the take home package station. This package is already set up for the participant, you are required to take the participant through; the weighed food record diary, food record example booklet, allocate and record four days for them to complete this on, electronic scales are provided if required, and then thorough the dietary diversity questionnaire, before the participant is equipped with the accelerometer.

17. Firstly, show the participant the weighed food record diary and explain this must be completed over the next four days i.e. if today's date of testing is Thursday the 12th of September, then the participant will complete a weighed food diary the following four days: Friday 13th, Saturday 14th, Sunday 15th and Monday 16th from when they wake up in the morning until when they go to bed at night. They must record the time of each meal, and weigh all food items they eat providing as much detail as possible when recording foods. We need four consecutive days of recording, which include at least one weekend day. If they go out for a meal, get them to describe the food as best they can, using the palm size as a portion tool or plate/bowl size.

18. Provide the participant with the food record example booklet, explain they can refer the picture numbers i.e. spaghetti bolognaise picture b.3 in their food diary if this helps for meals out or those they could not weigh.

19. Next, record the four days and dates (as explained above) in the participant's food diary record booklet, there are four lines at the beginning of the booklet to record this. Also record this on the calendar in the Explore pink folder. Explain that there are contact details on the front of the food record dairy which the participants can use if any questions arise while they are weighing their food and recording it.

20. If the participant does not have a set of electronic scales at home, please provide them with some. If there are none in building 27, please see PC. Check that the scales have batteries in them, and that they work. Record the scale ID number on the back of the calendar with the participant name and date. The participant will be given a courier bag to return the scales in

21. Finally, go through the Dietary Diversity Questionnaire with the participant. This is to be completed in 7 days' time when they take the accelerometer off. They only complete this questionnaire once, and emphasise how they must not look at their food record when completing this. The questionnaire is designed with a different purpose.

22. The weighed food record and the dietary diversity questionnaire need to be returned in the return envelope with the accelerometer after7 days. The courier bag with the scales can be sent back after the four days of recording are completed.

Appendix C. Standard Operating Procedure for the Food Record

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

Summary of food record SOP

Massey University

August 5, 2013

Complied by: Adrianna Hepburn

Approved by: Dr Rozanne Kruger, Dr Kathryn Beck

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

- Show participants the four-day food and food photo portion guide booklets, and give them a brief run down on its purpose and how to fill it out
- Set participant up at computer to watch the DVD which explains how to keep a food record.
- On completion of watching the DVD, check whether the participant has any questions regarding the completion of the food diary
- Emphasize the importance of being as honest and accurate as possible when filling out the food record, as it will allow a more accurate assessment of their current diet
- Assign participants dates that they need to complete the food diary – the four consecutive days following testing, including at least one weekend day.
- Ask participants to return the food record as soon as they have completed the last day of recording, via stamped addressed envelope. Participants will also be sent a email to remind them to complete and return the food record during the week after they have come in for testing
- Provide participant with electronic scales to weigh food if needed and a courier-stickered box to return the scales in.

Script:

We have a short video for you to watch about how to keep a weighed food record for four days.

*Once you have watched it I can answer any questions or queries you've got.*Watch video**

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

*The purpose of the weighed four-day food record is to allow us analyse the nutrient content of your current diet. It is important that you fill it out as accurately and honestly as possible. You need to record all the food and drink that you consume on four consecutive days – 2-3 weekdays and 1-2 weekend days. We will ask you to do the food record the four consecutive days starting from tomorrow (*write dates in diary). Do you think that you will be able to do that, on the days that we have filled in for you?*

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

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

Appendix D. Four-day weighed food record

MASSEY UNIVERSITY

COLLEGE OF HEALTH

TE KURA HAUORA TANGATA

Women's EXPLORE Study

Weighed 4 Day Food Record

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

If you have any questions, please contact EXPLORE staff on:

414 0800 (extn 41189) ***email: explore@massey.ac.nz***
or

Zara Houston 021 029 31620 AJ Hepburn 027 404 5351

All information in this diary will be treated with the strictest confidence.

No one outside the study will have access to this

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

What to do?

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

_____

_____

_____

_____

- If possible record food at the time of eating or just after – try to avoid doing it from memory at the end of the day.

- Include all meals, snacks, and drinks, even tap water.

- Include anything you have added to foods such as sauces, gravies, spreads, dressings, etc.

- Write down any information that might indicate **size or weight** of the food to identify the portion size eaten.

- Use a new line for each food and drink. You can use more than one line for a food or drink. See the examples given.

- Use as many pages of the booklet as you need.

Describing Food and Drink

- Provide as much detail as possible about the type of food eaten. For example

  brand names and varieties / types of food.

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

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

  baked, poached, boiled

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

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

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

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

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

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

Recording the amounts of food you eat

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

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

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

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

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

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

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

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

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

Example day

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

Date_____ DAY 1

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

Date_____DAY 1 continued

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

Recipes (Day 1)

Date_____ DAY 2

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

Date_____DAY 2 continued

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

Recipes (Day 2)

Date_____ DAY 3

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

Date_____DAY 3 continued

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

Recipes (Day 3)

Date_____ DAY 4

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

Date_____ **DAY 4 continued**

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

Recipes (Day 4)

Date_____ (spare pages)

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

Date_____ **(spare page**

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

Appendix E. Assumptions and decisions made from the NZWFFQ for each index component

NZW-HDI component	Assumptions and decisions made from NZWFFQ	Rationale	Question from NZWFFQ
Variety: Number of coloured fruits in each category (red, orange/yellow, purple/blue, green, white/brown)	-Fruit groups: red (apple, watermelon, strawberries); orange (oranges and mandarins, peaches, pineapple, mango, tamarillo); blue/purple (grapes, raisins and sultanas); green (feijoas, kiwifruit); and white/brown (pear, banana)	-Fruits allocated into their corresponding colour groups - Colours of fruit based on most popular choices e.g. apple (red), pear (white/brown	15 (3)
Variety: Number of coloured vegetables in each category (red, orange/yellow, purple/blue, green, white/brown)	-Vegetable groups: red (tomatoes and capsicum); purple/blue (beetroot); orange/yellow (kumara, pumpkin, carrots, sweet corn); green (sprouts, green beans, silver beet/spinach, brussel sprouts, courgettes, avocado); brown/white (potato, mushrooms, taro, turnips, onions, cauliflower, green bananas, yams)	- Vegetables allocated into their corresponding colour groups -Colours of vegetables based on most popular choices e.g. kumara (orange)	14 (3)
Fruit: Servings of fruit per day	-Types of fruit included in the score were fresh, frozen, canned or stewed fruits	-Incorporated into NZWFFQ summary question used	15 (2)
Vegetables: Servings of vegetables per day	-Types of fruit included in the score were fresh, frozen, canned or stewed fruits	-Incorporated into NZWFFQ summary question used	14 (2)

NZW-HDI component	Assumptions and decisions made from NZWFFQ	Rationale	Question from NZWFFQ
Grain foods: Servings of grain foods per day	-Includes bread, cereals, and starchy foods (rice, pasta, noodles) -Crackers and crisp bread excluded	-NZWFFQ questions provided information on servings of bread, different cereals, and starchy food only -EGSNZA includes breads, cereals, and starchy foods however crackers and crisp bread do not contribute to recommended daily servings of grain foods	5 (4), 6 (3), 7 (3)
Wholegrain foods: Proportion of wholemeal/wholegrain choices relative to total amount of grain foods	-Calculation of wholegrain foods included: wholemeal and wholegrain bread, brown rice, Weetbix, muesli, and porridge/oats -Calculation of total grains included: white bread, white rice, pasta, cornflakes, light and fruity cereals, chocolate based cereals	-Calculated as total whole grains/total grains x 100 -Unequal distribution of whole grain foods to refined foods in NZWFFQ, which would result in more refined grains contributing to the score. For this reason, wholegrain foods were paired with corresponding refined foods where possible (e.g. white bread was matched with wholegrain bread)	5 (5, 6), 6 (4), 7 (3)
Milk and milk products: servings of milk and milk products per day	-Milk, yoghurt, cheese (cheddar, edam, cream cheese, cottage cheese), flavoured milk, milk on breakfast cereals, and milk-based hot drinks only. -Ice-cream, cream, custard, milk puddings, and fermented/evaporated milk excluded	-Recommendations from guidelines includes milk, cheese, yoghurt contributes to daily servings -Selection of dairy products obtained from NZWFFQ	3 (4, 5, 6)

NZW-HDI component	Assumptions and decisions made from NZWFFQ	Rationale	Question from NZWFFQ
Legumes, nuts, seeds: Servings per day OR Kaimoana, eggs, poultry or red meat: Servings per day	-For legumes, nuts and seeds – cashew nuts, brazil nuts, peanuts, other nuts, and pumpkin seeds only	-Limited selection of nuts and seeds used due to data from NZWFFQ	8 (3), 9 (3), 10 (2), 14 (2), 13 (2), 19 (1)
Red meat	-Included beef, mutton, hogget, lamb or pork only	-Types of red meat obtained from NZWFFQ	8 (4)
Type of milk	-Types of milk used: whole milk, low fat milk, both types of milk	-Previous indices have used whole milk and low fat milk to distinguish differences in diet quality (McNaughton et al., 2008)	4 (2)
Trimming of fat from meat, removal of skin from chicken	-Based on always, occasionally, rarely, or never	-Previous indices have used that have used this criteria to distinguish differences in diet quality (McNaughton et al., 2008)	8 (2), 9 (2)
Salt: Salt used in cooking, salt used at the table	-Based on always, often, sometimes, or rarely	-Previous indices have used that have used this criteria to distinguish differences in diet quality (McNaughton et al., 2008)	19 (2, 3)
Takeaways: Takeaway consumption per week	-Takeaways includes both healthy and unhealthy takeaways		20 (1)

NZW-HDI component	Assumptions and decisions made from NZWFFQ	Rationale	Question from NZWFFQ
Sugary food (e.g. chocolate, cakes, biscuits): Number of servings from each category per week	-Included chocolate, cakes/loaves/muffins, lollies, sweet pies/pastries/tarts, puddings/desserts, plain/fancy biscuits only	-Types of high sugar foods obtained from NZWFFQ	18 (1) 19 (1)
Fluids: Frequency of consumption of beverages	-Included a total of 23 different beverages (e.g. coffee, tea, juice)	-Types of fluids obtained from NZWFFQ	17 (1, 2)
Fluids: Proportion of water consumed relative to total beverages	-Plain water only (250 ml)	-Water consumption obtained from NZWFFQ	16 (1)
Alcohol: Number of standard drinks per week	-Included a total of 11 different alcoholic drinks (e.g. beer, wine, sprits)	-Types of alcoholic drinks obtained from NZWFFW	17 (4)

Appendix F. Assumptions and decisions made from the FR for each index component

NZW-HDI component	Assumptions and decisions made from FR
Variety: Number of coloured fruits in each category (red, orange/yellow, purple/blue, green, white/brown)	-Fruit categorised based on the five different colours over the 4 days -Score depends on the number of different types of fruit -Serving size not considered
Variety: Number of coloured vegetables in each category (red, orange/yellow, purple/blue, green, white/brown)	-Vegetables categorised based on the five different colours over the 4 days -Score depends on the number of different types of fruit -Serving size not considered
Fruit: Servings of fruit per day	-Total number of servings for the 4 days calculated, average intake obtained -Weight in grams from each food item converted into volume (cups) -Fruit components of smoothies/juices added
Vegetables: Servings of vegetables per day	-Total number of servings for the 4 days calculated, average intake obtained -Weight in grams from each food item converted into volume (cups) -Potato fries excluded
Grain foods: Servings of grain foods per day	-Total number of servings for the 4 days calculated, average intake obtained -Weight in grams from each food item converted into volume (cups) -Mixed dishes broken down into separate components
Wholegrain foods: Proportion of wholemeal/wholegrain choices relative to total amount of grain foods	-Total number of servings for the 4 days calculated, average intake obtained
Milk and milk products: servings of milk and milk products per day	-Total number of servings for the 4 days calculated, average intake obtained -Weight in grams from each food item converted into volume (cups) -Mixed dishes broken down into separate components
Legumes, nuts, seeds: Servings per day OR Kaimoana, eggs, poultry or red meat: Servings per day	-Total number of servings for the 4 days calculated, average intake obtained -Mixed dishes broken down into separate components

NZW-HDI component	Assumptions and decisions made from FR
Red meat	-Amount of red meat consumed over 4 days converted into amount per week -Processed meats such as ham and bacon excluded
Type of milk	-Type of milk chosen depends on whether it is consumed >3 times (either low fat or whole milk) -Two types of milk consumed over the 4 days (both types of milk)
Trimming of fat from meat, removal of skin from chicken	-Observed in the raw food records and Foodworks database -Never/rarely = fat not trimmed/skin on -Often = fat trimmed/skin off 2 or 3 times -Always= fat trimmed/skin off all days
Salt: Salt used in cooking, salt used at the table	-Observed in the raw food records and Foodworks database -Salt used the table not be observed -Raw food records and Foodworks data checked for salt added to cooking -Never/rarely = no salt added -Sometimes = salt added 1 or 2 times -Usually/always = salt added 3 or 4 times
Takeaways: Takeaway consumption per week	-Observed in the raw food records and Foodworks database -Total number of takeaways consumed over the 4 days calculated, average consumption obtained
High sugar food (e.g. chocolate, cakes, biscuits): Number of servings from each category per week	N/A
Fluids: Frequency of consumption of beverages	-Number of fluids for the 4 days calculated, average intake obtained -Smoothies included
Fluids: Proportion of water consumed relative to total beverages	N/A

NZW-HDI component	Assumptions and decisions made from FR
Alcohol: Number of standard drinks per week	-Number of servings of water for the 4 days calculated, average intake obtained -Amount of alcohol consumed over 4 days converted into amount per week

FR, Food Record; NZWFFQ, New Zealand Women's Food Frequency Questionnaire

Appendix G. Conversion factors used for the NZW-HDI derived from the FR

Food	Measurement	Food	Measurement
Boiled Vegetables	**1 cup**	**Fruit**	**1 cup**
Carrot	145 g	Banana	250 g
Spinach	150 g	Apple	132.5 g
Broccoli	165g	Pear	175 g
Silverbeet	72.4 g	Orange	174 g
Asparagus	136 g	Mandarin	195 g
Potato (boiled)	162.5 g	Blueberry	164 g
Kumara	346.6 g	Blackberry	160 g
Pumpkin	217 g	Plum	174 g
Parsnip	140 g	Apricot	260 g
Cabbage	145 g	Peaches	264 g
Mixed vegetables	132.5 g	Tangelo	230 g
Raw vegetables	**1 cup**	Rhubarb	265 g
Corn	265 g	Grapes	160 g
Spring onion	106 g	Kiwifruit	257 g
Carrot	130 g	Pineapple	165 g
Lettuce	57.5 g	Dried fruit	175 g
Spinach	42.9 g	Watermelon	169 g
Beetroot	142.5 g	**Grains**	**1 cup**
Tomato	167 g	Weetbix	44.4 g
Onion	175 g	Oats	45 g
Avocado	237 g	Special K	21 g
Cabbage	104 g	All Bran	39 g
Broccoli	82 g	Just Right	27.5 g
Cauliflower	138 g	Couscous	165 g

Food	Measurement	Food	Measurement
Raw vegetables	**1 cup**	Noodles	225 g
Capsicum	130 g	Muesli	71 g
Peas	165 g	Pasta	120 g
Beans	121 g	Rice, brown	205 g
Eggplant	188 g	**Grains**	**1 cup**
Lettuce	58 g	Rice, white	162 g
Cucumber	147 g	Bread	28 g
Courgette	127 g		
Celery	223 g	**Miscellaneous**	
Olives	257 g	Small glass of red wine	100 mL
Sweetcorn	175 g	Bottle of beer	330 mL
Mushroom	68 g	Spirits	30 mL
Capsicum	130 g	Cake	72 g
Peas	165 g	Chocolate bar	61 g
Beans	121 g	Biscuits	21 g
Eggplant	188 g	Lollies	14 g