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Validity and Reliability of a Dietary Index for a Child's Eating (DICE) to Assess Diet Quality of Children Living in New Zealand

A thesis presented in partial fulfillment of the requirement for the degree of Master Science in Human Nutrition

At Massey University, Albany,
New Zealand

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2016

Abstract

Background: At present, in New Zealand, there is no valid and reliable dietary index, which can assess the adherence of children to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2 -18 years)'.

Aim: To examine the validity and reliability of the Dietary Index for a Child's Eating (DICE) in children aged 2 to 8 years living in Auckland, New Zealand.

Methods: Caregivers of healthy children (2-8 years) living in NZ were recruited by email and print advertising. Caregivers completed a four day estimated food record (4DFR) for their child, and completed the DICE online on 2 separate occasions, eight weeks apart. The DICE consists of 17 questions that refer to current statements in the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)', with greater adherence to guidelines indicated by a higher score (maximum 100). The 4DFR was the reference method for assessing validity of the DICE, and the repeated completion of the DICE questionnaire for assessing its reliability. Relative validity was assessed by comparing the DICE total score and component sub-scores with 4DFR total score and the same 4DFR component sub-scores from the questionnaire using Wilcoxon signed rank test, Spearman correlation coefficients, cross-classification, and weighted kappa (κ) statistic. For evaluating construct validity, the DICE (total score and individual components) were compared with energy and nutrient intake extracted from the 4DFR using Pearson's rank correlation coefficient and linear contrast analysis. Intra-class correlation coefficients (Cronbach's α) were used to assess the reliability of DICE.

Results: From a possible score of 100, the mean ± SD of DICE was 78.2 ± 11.5 (range from 47 to 100) and the 4DFR was 73.8 ± 10.8. Pearson's correlation coefficient showed a significant, high correlation between the total scores for DICE and 4DFR ($r = 0.72$; $P < 0.001$). Results from the weighted κ-statistic also showed that the DICE total score and 4DFR total score had very good agreement ($\kappa = 0.94$). There was a significant positive relationship between the DICE total score and vitamin C ($r = 0.53$), folate ($r = 0.45$), and calcium ($r = 0.44$) ($P < 0.001$). Results from linear contrast analysis showed that higher intake of fibre, vitamin C, vitamin A, vitamin D, folate ($P < 0.05$), and calcium ($P < 0.001$) were associated with increasing tertile of the DICE total score. Almost perfect agreement (0.87) was found through the Intra-class correlation coefficient for reliability test ($P < 0.001$).

Discussion and Conclusion: Results from this study demonstrated that DICE is a valid and reliable tool for the assessment of children's adherences to a health-promoting diet, as suggested in the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2 -18 years)'.

Acknowledgements

I would like to sincerely thank the following people for their contributions to this research and report:

- My supervisors, Dr. Cath Conlon, Dr. Kathryn Beck, and Dr. Pamela von Hurst for their constant encouragement, patience, support, and guidance.
- Owen Mugridge for his support in recruiting participants and data collection.
- The participants of this study for their time and commitment to the research.
- My husband for his ongoing support and encouragement.

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List of abbreviations

Adequate Intake	AI
Australian Child and Adolescent Recommended Foods Score	ACARFS
Australian Recommended Food Scores for Preschoolers	ARFS-P
Brazilian Healthy Eating Index Revised	BHEI-R
Coronary Heart Disease	CHD
Diet Quality Index	DQI
Diet Quality Index for Adolescents	DQI-A
Diet Quality Index for NZ Adolescents	NZDQI-A
Diet Quality Index for Preschool Children	DQI-CH
Diet Quality Index-International	DQI-I
Dietary Guideline Index for Children and Adolescents	DGI-CA
Dietary Index for a Child's Eating	DICE
Estimated Average Requirement	EAR
Eating Choices Index	ECI
Finnish Children Healthy Eating Index	FCHEI
Food Frequency Questionnaire	FFQ
Food-Based Dietary Guidelines	FBDG
Four day Food Record	4DFR
Gram	g
Healthy Eating Index	HEI
Healthy Eating Index for Canadian	HEI-C
Healthy Eating Index-2005	HEI-2005
High Fat, Sugar, and Salt foods and snacks	HFSS
Intra-class Correlation Coefficient	ICC
Kilo calories	Kcal
Kolmogorov-Smirnov	K-S
Mediterranean Diet Quality Index for children and adolescents	KIDMED
Mediterranean Diet Score	MDS
Mediterranean Lifestyle Index	MEDLIFE

Microgram	μ g
Milligram	mg
Monounsaturated Fatty Acids	MUFA
New Zealand	NZ
Number	n
Nutrient Reference Values	NRVs
Nutrient-Rich Food index	NRF-index
P-value	*P*
Polyunsaturated Fatty Acids	PUFA
Preschoolers Diet–Lifestyle Index	PDL-Index
Recommended Dietary Intakes	RDI
Revised Children's Diet Quality Index	RC-DQI
Saturated Fatty Acids	SFAs
Serving per day	Serve/d
Shapiro-Wilk	S-W
Standard Deviation	SD
Statistical Package for the Social Science	SPSS
Television	TV
Trans Fatty Acids	TFAs
Update the Healthy Eating Index-C 2009	HEIC-2009
Upper Level of Intake	UL
US Department of Agriculture	USDA
Youth Healthy Eating Index	YHEI

Chapter 1: Introduction

One of the most significant factors in the prevention of non-communicable diseases and achievement of optimal health is a high quality diet (Gubbels, van Assema, & Kremers, 2013). Dietary habits are usually established at an early age and tend to be followed throughout life. Therefore practicing optimal dietary habits during childhood may have a preventive effect against chronic diseases during adulthood (Mikkila, Rasanen, Raitakari, Pietinen, & Viikari, 2004).

In clinical settings and epidemiological studies, low cost and accurate dietary assessment methods are the primary tools for assessing the link between dietary intake and health outcomes. There are various methods available for assessing dietary intake (Lyu, Hsu, Chen, Lo, & Lin, 2014) including 24-hour recalls, food records, diet history, food frequency questionnaires (FFQ) (Mann & Truswell, 2007), and more recently, technology-based instruments (Ngo et al., 2009; Stumbo, 2013). The weighed or estimated food records and 24-hour recalls are considered as 'daily food consumption methods' since they measure the quantity of consumed food and then provide accurate dietary information about daily nutrient intakes. The FFQ and diet history are categorised into 'recalled usual or average food consumption' because they assess habitual intake of food groups and/or specific classes of foods (Lee & Nieman, 2010). These two methods principally provide information relating to foods, food groupings or dietary patterns rather than nutrient intakes, however with the application of appropriate modification they can supply data about individuals' habitual nutrient intakes (Mann & Truswell, 2007). In all these dietary assessment methods, it can be difficult to collect accurate and reliable dietary information from children (Livingstone, Robson, & Wallace, 2004). This can be due to inadequate literacy levels, lack of cognitive ability, and difficulties in portion size estimation of children (Livingstone & Robson, 2000). It has been shown that a child younger than approximately eight years old is not able to recall foods or estimate portion size accurately and also does not have enough ability to conceptualise the time frame and frequency of food consumption (Livingstone & Robson, 2000). Therefore children's parents usually participate as proxy reporters for collecting dietary data in research studies (Livingstone & Robson, 2000).

Following collection of dietary information the data must be analysed. Traditionally dietary information has been converted into an individual's nutrient, food or food

grouping intake and then compared with standard references to determine how healthy an individual's diet is (Jacobs Jr, 2012). Traditional assessment methods provide the opportunity for researchers to investigate the relationship between individual nutrients or food and disease outcomes, either from inadequate intakes or over consumption of a specific nutrient, food or food grouping (Cited by Waijers, Feskens, & Ocke, 2007). However, there are some limitations related to these traditional approaches of dietary assessment. People eat whole foods or combinations of foods, which usually contain various nutrients and non-nutrient dietary components (Mertz, 1984) that may interact (e.g. calcium and iron), which can affect the nutrients' bioavailability, absorption, and metabolism (Lynch, 1997). However, these methods are not able to provide adequate information about the relationship between foods, food groups and nutrient combinations, and their interactions (Nicklas, 2004) and synergies (Jacobs, Gross, & Tapsell, 2009). These limitations show the necessity of emphasising the whole diet and diet quality rather than single nutrients or food, which are not consistent with the nature of dietary intakes.

More recently, dietary patterns, which consider the totality of the diet have been used to investigate dietary intake (Hu, 2002). Analysis of dietary patterns provides a chance to assess the overall diet (Hu, 2002) and combinations of various components of the diet such as nutrients, foods, food groups, and eating habits (Gerber, 2001). There are two different approaches for assessing dietary patterns including empirical methods (e.g. most commonly factor analysis and cluster analysis) and theoretical methods (e.g. diet quality indices). In empirical methods, dietary patterns are generated through statistical analysis from collected dietary information (Newby & Tucker, 2004). Factor analysis reduces dietary data into dietary patterns based on inter-correlations between dietary items (Martinez, Marshall, & Sechrest, 1998), whereas cluster analysis groups individuals with similar dietary patterns into mutually exclusive categories (Moeller et al., 2007).

Recently, diet and disease research findings have emphasised diet quality. Diet quality indices can be simple, short, and effective dietary assessment tools, which can provide information about overall diet quality (Bell, Golley, & Magarey, 2013). Dietary indices are designed according to existing national dietary guidelines and recommendations (Moeller et al., 2007) or desirable dietary patterns (e.g. Mediterranean) and they usually provide a summary score (Waijers et al., 2007), which indicates how closely an

individual adheres to an optimal diet (McNaughton, Ball, Crawford, & Mishra, 2008). Consequently they are easy to understand and interpret by clients and health specialists alike. Since dietary indices can provide valuable and comprehensive information about dietary patterns, they can be used as a more practical method for dietary analysis among children (Lazarou & Newby, 2011). In terms of determining a child's diet quality, it is very important to assess dietary intake accurately (Burrows, Martin, & Collins, 2010).

In nutrition assessment, the accuracy of information is a major challenge (Bountziouka & Panagiotakos, 2010). It is important that dietary assessment methods are valid and reliable (Kimberlin & Winterstein, 2008). Validity refers to how well a dietary assessment method measures what it intends to measure (i.e. how close measurements are to the actual (true) dietary intake values) (Livingstone et al., 2004; Rose & Barker, 1978). It is common for dietary assessment tools to be compared or validated against another similar method (e.g. weighed food record) or by direct observation of meal consumption (Baxter, Smith, Nichols, Guinn, & Hardin, 2006; Lytle et al., 1993; Weber et al., 2004). Reliability refers to the consistency of dietary intake information after re-administration of the same questionnaire at different times to the same individuals (Kimberlin & Winterstein, 2008).

Previous research has shown that dietary indices can be a useful tool to identify associations between diet quality and disease in adults (Kant, 1996, 2004; Michels & Schulze, 2005). There are a number of dietary indices available for children. It has been shown that there is an association between child and adolescent diet quality and the risk of chronic diseases in later life (Azadbakht, Akbari, & Esmaillzadeh, 2015). Nutritional recommendations and guidelines differ between countries, therefore it is important that diet quality indices are developed which are specific to the country of interest (Bell et al., 2013). A number of children's diet quality indices have been developed around the world including the 'Revised Children's Diet Quality Index (RC-DQI)' in America (Kranz, Hartman, Siega-Riz, & Herring, 2006), the updated 'Healthy Eating Index-C (HEI-C)' for Canadian children (Woodruff & Hanning, 2010), and the 'Mediterranean Diet Quality Index (KIDMED index)' for Spanish children and adolescents (Serra-Majem et al., 2004). Dietary indices have been developed for Australian children (Burrows et al., 2014; Golley, Hendrie, & McNaughton, 2011; Marshall, Watson, Burrows, Guest, & Collins,

2012). Wong et al. (2013) developed and validated the 'Diet Quality Index for New Zealand Adolescents (NZDQI-A)'. However, to our knowledge, there are no valid dietary indices available for children living in New Zealand (NZ). This highlights the need for a valid and reliable dietary index in this population group. A valid and reliable dietary index for use in children aimed at assessing adherence to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' (Ministry of Health, 2012) will be useful in future clinical applications, public health settings, and research studies.

The Human Nutrition team at Massey University has recently developed the 'Dietary Index for a Child's Eating (DICE)'. The DICE was designed according to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young people (Aged 2-18 years old)' (Ministry of Health, 2012) and aims to identify children at risk of not adhering these guidelines. Prior to use, the DICE needed to be checked for validity (against a 'gold standard' method) and reliability (comparing its first and second time administration).

1-1. Aim

To examine the validity and reliability of the Dietary Index for a Child's Eating (DICE) in children aged 2 to 8 years living in Auckland, New Zealand.

1-2. Objectives

- To investigate the relative and construct validity of the DICE against a four day estimated food record (4DFR)
- To examine the reliability of DICE by having participants complete the DICE on two occasions, eight weeks apart.

1-3. Hypothesis

We hypothesised that DICE would be a valid and reliable dietary assessment method for assessing diet quality of children aged 2 to 8 years.

1-4. Structure of thesis

Following this introduction chapter, chapter 2 consists of a review of the relevant literature. Chapter 3 includes all the details regarding the methodological procedures of

the current study, from recruitment through to data analysis. Chapter 4 describes the results of the study. Chapter 5 includes a discussion about the findings of the current study in the context of current literature, followed by an assessment of the strengths and limitations of this research, recommendations for future research and final conclusions.

1-5. Researchers' contribution

Researchers	Contributions
Maryam Delshad Siyahkaly	MSc student • Main researcher • Conceptualisation and study design • Checking food diaries • Coding food diaries • Scoring food diaries • Checking Foodworks data • Data entry • Performed statistical analysis • Methods and protocols • Results interpretation • Author of thesis
Dr Cathryn A Conlon	Academic supervisor and assistance including: • Conceptualisation and study design • Methods and protocols • Results interpretation • Thesis revision
Dr Kathryn L Beck	Academic supervisor and assistance including: • Conceptualisation and study design • Methods and protocols • Statistical analysis • Results interpretation • Thesis revision
Dr Pamela R von Hurst	Academic supervisor and assistance including: • Conceptualisation and study design • Application for ethics • Methods and protocols • Results interpretation

	• Thesis revision
Owen Mugridge, MSc	Responsible for: • Project coordination • Participants recruitment • Data collection • Data protection and collation • Website design
Jeanette Rapson	Responsible for: • Entered the original food diaries • Research assistant
Mikaela Makker	Responsible for: • Entered the original food diaries • Research assistant
Aimee Waring	Responsible for: • Entered the original food diaries • Research assistant

I declare that my role in the study as indicated above is representative of my actual contribution.

Maryam Delshad Siyahkaly

Chapter 2: Literature review

The purpose of this chapter was to review the literature on diet quality assessment in children, including the development of dietary assessment tools, and methods used to assess their validity and reliability. A literature search was conducted using the Google scholar, Science Direct and PubMed databases using the key words: diet index, diet indices, dietary assessment, dietary measurement, diet score, index development, validation, reliability, reproducibility, repeatability, healthy children, and New Zealand (NZ). All the titles and abstracts from research results were retrieved in order to determine whether they were appropriate for including in this review. In order to be included, articles needed to be in the English language and their full texts available. Reference lists from each article were manually searched in order to determine further literature. Published articles related to children dietary indices from 1990 to 2016 were included into this review.

2-1. Dietary intake/quality in children

Diet is one of the most modifiable and significant factors in preventing chronic diseases and supporting optimal health (Gubbels et al., 2013). The early years of life are important not only for growth and development, but also for shaping future health behaviours. Therefore diet quality and nutritional adequacy are crucial. Dietary habits formed in early life often continue into adulthood (Mikkila et al., 2004), so adopting an optimal diet during childhood may have a preventive effect against non-communicable diseases (e.g. obesity) later in life (Singh, Mulder, Twisk, van Mechelen, & Chinapaw, 2008). Factors including the family environment and early food-related experiences contribute to the young child's dietary habits (Birch, Savage, & Ventura, 2007).

Studies have revealed that long-term unhealthy dietary habits are associated with the prevalence of some lifestyle-related diseases such as overweight and obesity (Kotani et al., 1997). In recent years, childhood overweight and obesity have become a global health problem, with a prevalence of 41-million overweight or obese children less than five years old in 2014 (World Health Organization, 2016). According to a New Zealand Health Survey in 2011/12, 21% and 10% of children and adolescents (aged 2-14 years) living in New Zealand were overweight and obese respectively (Ministry of Health, 2016). There is a greater risk for overweight and obese children to develop chronic

diseases such as type II diabetes, metabolic syndrome, and cardiovascular disease at a younger age, and obese children tend to become obese adults (Baker, Olsen, & Sorensen, 2007; Freedman et al., 2005; Vanhala, Vanhala, Kumpusalo, Halonen, & Takala, 1998). It has been shown that the lifestyle and diet of overweight and obese children is characterised by high consumption of fizzy/sweetened beverages, fast food, energy-dense snacks, larger portion sizes and nutrient-poor foods (Austin et al., 2005), whilst consuming fewer fruits, vegetables, and wholegrain (Wall, Thompson, Robinson, & Mitchell, 2013). More recently, dietary assessment methods have focused on evaluation of diet quality (Carvalho, Dutra, Pizato, Gruezo, & Ito, 2014). Children who follow a healthy diet usually have higher diet quality, better nutrient intake and consequently better health in adulthood (Deshmukh-Taskar et al., 2010; Rasmussen et al., 2006; Sjoberg, Hallberg, Hoglund, & Hulthen, 2003). It has been suggested that the dietary patterns of children should be assessed to allow the identification of those with poor dietary habits and the opportunity to offer a solution for their dietary problems (Kobayashi et al., 2010).

2-2. Dietary assessment in children

There are several issues associated with assessing dietary intake in children. Children (under 7-8 years old) do not have the cognitive ability to accurately recall and record their diets (Livingstone et al., 2004), and they may have limited knowledge about food and food preparation methods (Livingstone & Robson, 2000; Rockett & Colditz, 1997; Smith, Baxter, Hardin, Guinn, & Royer, 2011). Therefore it is necessary to involve their parents or caregivers in their dietary evaluation (Foster, Adamson, Anderson, Barton, & Wrieden, 2009; Hunsberger et al., 2013; Knuiman, Rasanen, Ahola, West, & van der Snoek, 1987).

In both clinical and research settings it is important that valid, reliable and low cost dietary assessment tools are available to assess the link between dietary intake and health outcomes. Moreover these methods should not impose a heavy burden on the participants and/or researchers (Bonifacj, Gerber, Scali, & Daures, 1997). Previous work has described different dietary assessment methods in detail (Lee-Han, McGuire, & Boyd, 1989; Lyu et al., 2014). In general, there are two different methods for collecting dietary

intake data, ‘daily food consumption’ and ‘recalled usual food consumption’ (Lee & Nieman, 2010). The weighed or estimated food records and 24-hour recalls are two kinds of ‘daily food consumption methods’, which can measure the quantity of food consumed and supply precise dietary information regarding actual daily nutrient consumption. The food frequency questionnaire (FFQ) and diet history are ‘recalled usual or average food consumption’ methods and typically assess habitual intake of food groups and/or specific classes of foods (Lee & Nieman, 2010). It should be considered that in all these dietary assessment methods, children’s parents or caregivers usually participate as proxy reporters for obtaining dietary data (Livingstone & Robson, 2000).

These conventional methods and other new instruments for assessment of dietary intakes will be briefly discussed below. They are summarised in Table 2-1.

2-2-1. Food records – weighed and estimated

In the l930s the weighed food record was designed by Widdowson and McCance (Rockett & Colditz, 1997) and for many years, it has been one of the main tools for collecting information about what people eat and drink (Hill & Davies, 1999). There are two techniques for recording food intakes including the estimated food record and weighed food record. Participants either estimate all foods and drinks consumed using tools such as household measures or weigh their food and drinks using scales. Participants are asked to record food and drinks for a specified period of time such as 3, 4 or 7 days. In the 3 or 4 days food record, usually one weekend day and the rest from week days in the form of continuing or alternative days, are included (Lee-Han et al., 1989). It is necessary to give the participants complete instructions and details about how to estimate or weigh foods and drinks, including leftovers. Participants also need to be specific in their recording of types, brands and presentation of foods (e.g. cooked versus raw) (Lassale et al., 2009).

Since the weighed food record provides a precise measure of the amount of foods and beverages, which are consumed during a specific period of time, it is usually considered as a ‘gold standard’ method for evaluating dietary intake (Rockett & Colditz, 1997). However, there are some drawbacks. While researchers usually ask participants to not change their food patterns while completing the food record, participants may reduce the

number and types of different foods eaten to reduce the burden of recording or to appear to consume a healthier diet. Another problem for researchers is that completing the food record requires literacy, therefore recruiting educated participants is essential, but potentially causes bias in a sample (Rockett & Colditz, 1997).

2-2-2. 24-hour recall

The 24-hour recall method requires the participant to recall all foods and beverages consumed, including cooking methods and brand names (if possible), during the previous 24 hours. Participants often use household measures (e.g. spoon, cup, or bowl) or photographs of food to help estimate the amount of foods and drinks consumed (Lee-Han et al., 1989).

The advantages of the 24-hour recall include that it is suitable for different ethnicities, easy to use, and has low participant burden (relative to the food record), and is suitable for illiterate participants (Mann & Truswell, 2007). In reporting the results of the 24-hour recall, day-to-day variation should be considered as a one-day recall is not an accurate representation of a person's intake (Shim, Oh, & Kim, 2014). Other disadvantages of the 24-hour recall include reliance on memory, therefore it is an unsatisfactory tool for use in the elderly or young children, and it requires a trained interviewer to administer (Mann & Truswell, 2007). Similarly to the food record, under-reporting is also a concern (Shim et al., 2014).

2-2-3. Food frequency questionnaire

One of the most popular questionnaires used in nutrition research is the food frequency questionnaire (FFQ) (Willett, 1998), which can collect qualitative or semi-quantitative information about food consumption (Mann & Truswell, 2007). The FFQ is usually a self-administered questionnaire, in which the participant reports the frequency of intake of foods and beverages consumed. The FFQ may or may not consider the portion size of foods consumed. In some, participants describe the usual portion size consumed, and in others standard sizes are used for estimating foods or nutrient intakes (Wakai, 2009). In the semi-quantitative FFQ, the questionnaire is modified to quantify the total amount of each food item (Mann & Truswell, 2007) by multiplying the portion sizes by the

consumption frequencies (Serdula, Alexander, Scanlon, & Bowman, 2001). By adding all amounts of food items in the list, the total daily intakes of foods, food groupings or nutrients can be obtained (Wakai, 2009).

The FFQ can include different numbers of food items. In some studies the 'short cut method' is used in order to decrease participant burden. The participants are asked to list only particular food items, which contain the nutrient/s of interest, e.g. only foods containing vitamin E in cancer studies or calcium-containing foods in bone studies. Since dietary intakes are related to participants' demographic, ethnicity and social habits, it is necessary for the FFQ to be adapted to the target population in order to accurately reflect the dietary intake of participants (Wakai, 2009). The FFQ is a cost and time effective questionnaire, which can estimate typical dietary intake with high response rate and low participant burden. In this method the participant is less likely to alter his/her eating habits. However, it has some disadvantages such as its reliance on memory, requiring literate participants, and it needs to be specific to the study population (Mann & Truswell, 2007).

2-2-4. Diet history

In the l940s, Burke designed the diet history method (Rockett & Colditz, 1997). The diet history is usually conducted as an interview to obtain an overall idea of the individual's usual dietary patterns and food intake over varying time periods (e.g. past month, six months, or last year) (Mann & Truswell, 2007). The diet history usually consists of a 24-hour recalls to collect general information about meal patterns, meal times, and snack habits, and a FFQ in order to identify habitual consumption of foods and drinks and food preparation methods not covered by the 24-hour recalls. Some also include a 3-day estimated food record as a cross-check (Mann & Truswell, 2007). Compared to food records, it has a relatively low participant burden (Mann & Truswell, 2007). However, compared to the weighed food record, a diet history usually estimates a higher intake than actual values (Shim et al., 2014). Since it relies on the participant's memory and literacy to estimate correct portion size, it is therefore not suitable for use in children and elderly people (Mann & Truswell, 2007).

2-2-5.Other novel methods

Conventional methods of assessment of dietary intake include food records, 24-hour recalls, FFQs and diet histories (Mann & Truswell, 2007). The appearance of computers, mobile phones, and web-based instruments has prompted the improvement of dietary assessment (Illner et al., 2012) from self-completed methods to record dietary food intake and manual calculation of nutrient intake, to technology-based instruments and automatic calculations (Stumbo, 2013). For example, the emergence of mobile phones with embedded cameras and wireless transmission has given researchers the opportunity to automatically record and identify food items via an image (Khanna et al., 2010).

Although, using technology provides a chance to measure dietary intakes with more accuracy, these methods have their own limitations and it is important to consider any drawbacks when assessing dietary intake (Astell et al., 2014). For example computer and mobile phone technologies are not yet sophisticated enough to ensure the accurate recognition of food items, nor evaluate the quantity of a food through photos with 100% accuracy (Martin et al., 2014). Moreover, certain programs and features of technology-based methods are usually expensive and require a certain set of knowledge and expertise for their operation and use. Furthermore dietary recording through these technologies could be problematic for those who have little experience with high-tech devices (Long et al., 2010). Therefore training participants on how to properly use new technologies could be more difficult compared to the traditional dietary assessment methods (Long et al., 2010).

The strengths and limitations of dietary assessment methods are summarised in Table 2-1.

Table 2-1. Dietary assessment methods

Methods	Data Collection	Strengths	Limitations
Estimated or weighed food record	•Considers usual dietary patterns during specific time (e.g. 3, 4, or 7 days)	•Weighed food record is a precise method •Is considered as a gold standard •Does not require an interviewer •Does not have recall bias	•Has a high participant burden •Needs high participant motivation •Time consuming •Can affect normal dietary patterns •Needs to follow specific instructions •Needs literacy •Is not suitable for children*
24-hour recall	•Considers eating habits during past 24 hours	•Has a low participant burden •Household measures are acceptable	•Relies on memory •Does not consider day to day variation •Does not consider overall dietary patterns •Requires a trained interviewer •Unsatisfactory method for young children*
Food frequency questionnaire (FFQ)	•Considers the serving size and frequency of all foods and beverages consumed during specific period of time (e.g. past month or year)	•Is a self-administered questionnaire •Estimates typical dietary intake •Is a cost effective and time saving method •Does not alter participants' eating habits •Has low participant burden	•Needs to be adapted to target group •Relies on memory (recall bias) •Should be developed to be specific for the study population •Requires literate participants •Estimating serving size is difficult •Is not suitable for children*
Diet history	•Considers usual dietary patterns during long specific periods of time	•Estimates typical meal intake •Provides information about eating habits and food preparation	•Expensive •Time consuming •Requires a nutritionally trained interviewer •Is not suitable for children *
Other new methods (Technology-based methods)	•Considers usual diet intake	•Low researcher and participant's burden •Can be convenient •Does not rely on memory so can be more accurate •Can be used in children	•Requires more knowledge and expertise •Needs technology skills •May need internet connection •Is expensive

Note. Table adapted from Shim et al. (2014) and Mann & Truswell (2007).
* Young children (< 8 years old) are not able to recall foods or estimate portion size accurately and also do not have the ability to conceptualize the time frame and frequency of food consumption (Burrows et al., 2010; Livingstone & Robson, 2000). Parents or caregivers usually complete these questionnaires on behalf of their children.

2-3. Analysis of dietary data

Analysis of data regarding an individual's diet has two different approaches, traditional methods and more recent approaches. Traditional approaches focus on nutrients, foods and food groups. Dietary patterns including diet quality indices, which consider the whole diet, are more recent approaches.

2-3.1 The traditional approach-determination of nutrients and food intakes

In traditional approaches, dietary information is often converted into nutrient and food group intakes to compare with recommendations (Jacobs Jr, 2012). In order to calculate the amount of nutrients from foods consumed, food composition data is used. Country specific 'food composition tables' or 'nutrient databases' are designed to provide food composition information (Mann & Truswell, 2007). Before assembling food composition data, it is crucial to consider relevant food items and commonly consumed foods types for the population of interest. Availability of consumed food nutrient values within the nutrient database, precision, and accuracy of the food composition data should be investigated prior to use (Mann & Truswell, 2007).

2-3-2. Evaluation of nutrients and food intakes

Nutrient reference values (NRVs) and food-based dietary guidelines (FBDG) are used to compare nutrient or food data with standard references (Ministry of Health, 2005; World Health Organisation, 2003b) to determine how healthy an individual's diet is (Mann & Truswell, 2007). These two approaches are based on current nutritional knowledge and are specific for each country.

The NRVs are evidence-based recommendations for dietary intakes of macro and micronutrients across the lifecycle (Ministry of Health, 2005). The NRVs are a set of recommendations, which include: estimated average requirement (EAR), recommended dietary intakes (RDI), adequate intake (AI), estimated energy requirement (EER), and upper level of intake (UL) (National Health and Medical Research Council, 2006) (see Table 2-2 for definitions). An individuals' nutrient intake data can be compared against the NRV's (Ministry of Health, 2005).

Table 2-2. Definitions of the nutrient references values (NRVs)

Estimated average requirement (EAR)
Estimates average values for each nutrient in order to provide daily requirements in different age and gender groups for 50% of the population.
Recommended dietary intake (RDI)
Refers to consuming adequate levels of essential nutrients for 97% of the healthy population.
Adequate intake (AI)
Based on experimental or observational information, estimates values for nutrient intake, which are assumed to be adequate.
Estimated energy requirement (EER)
Estimates average values for dietary energy intake in order to provide energy balance in defined 'age, gender, weight, height, and physical activity' groups of healthy adults.
Upper level of intake (UL)
Refers to the highest values of a nutrient, at which level regular intake does not lead to adverse effects

Note. Table adapted from Ministry of Health (2005).

The FBDGs provide positive messages related to food and beverage selection, which can guide people to adequate dietary intakes and meet individuals' nutrients requirements. FBDGs are therefore an ideal way of communicating healthy eating messages to the general population (World Health Organisation, 2003b). The FBDGs are extracted from the best available scientific evidence and can be specified for each country according to their dietary patterns or public health problems (Vorster, Badham, & Venter, 2013). They are designed for the general population and since FBDGs categorise food items into food groups these food-based messages are easier for the general public to follow and understand (Löwik, Hulshof, & Brussaard, 1999).

In New Zealand, FBDG have been developed specifically for children and young people aged 2 to 18 years (Keller & Lang, 2008). The FBDG are freely available and are well used by public health professionals in New Zealand but wider distribution to specific population groups though the mass media has been more limited (Keller & Lang, 2008).

2-3-3. Limitations of single nutrient and food approaches

There are some limitations related to the traditional approaches of assessing dietary intake. People eat whole foods, which usually consist of different nutrient and non-nutrient dietary components (rather than nutrients in isolation) (Mertz, 1984). There are also food interactions and nutrient inter-correlations (e.g. calcium and phosphorous are often found in the same foods). Nutrient interactions can affect the nutrients' bioavailability, absorption, and metabolism. Assessing nutrients or food intake in isolation does not provide information about their unique combinations, interactions, (Nicklas, 2004) and synergistic relationships (Jacobs et al., 2009). These factors highlight the importance of considering the whole diet in addition to single nutrients or food/food groups.

2-4. Dietary pattern analysis

Research findings regarding diet and disease outcomes have recently focused on dietary patterns or diet quality rather than emphasising single foods or nutrients. In nutritional epidemiology, dietary patterns are an alternative approach for describing the total diet (Marshall et al., 2012; McNaughton et al., 2008) and the combination effect of foods, food groups and nutrients, their interactions, and their synergistic relationships (Gerber, 2001). Through measuring dietary patterns, we are able to assess adherence to dietary guidelines and monitor populations over time (McNaughton et al., 2008). Dietary patterns can be used as predictors of disease or as a summary of dietary behaviors to investigate interactions with other health behaviors or confounding of other exposure-disease relationships (McNaughton et al., 2008).

Empirical methods (most commonly, factor analysis and cluster analysis) and theoretical methods (diet quality indices or healthy eating indices) are two different approaches for assessing dietary patterns, which are summarised in Table 2-3.

2-4-1. Empirically derived dietary patterns

Factor analysis

Factor analysis is a statistical method to define dietary patterns and assess eating habits related to diet-disease relations (Martinez et al., 1998).

Dietary information is commonly collected through 24-hour recalls, food records, and FFQs (Lee-Han et al., 1989). Factor analysis determines dietary patterns based on inter-correlations between dietary items (Martinez et al., 1998), which can then be used for investigating the relationship between dietary patterns and health outcomes (Hu, 2002). Martinez et al. (1998) argued that factor analysis includes high levels of researcher's decisions (e.g. which variables include) when defining the dietary pattern.

There are limited researches that investigate the dietary patterns of children using factor analysis. For example, in China, Zhang et al., (2015) identified three dietary patterns using 24-hour recalls and factor analysis including 'modern', 'traditional north', and 'traditional south' in children. There was an association between the 'modern' and 'traditional north' dietary patterns and a higher chance of childhood obesity.

Only one study has investigated the dietary patterns of children living in New Zealand. Using factor analysis Wall et al., (2013) showed three dietary patterns among 3.5 to 7 years old children including 'junk', 'traditional', and 'healthy'. The 'junk' food pattern consisted of candies, hamburgers, soft drinks, chips, and chocolate. Fruits, vegetables, and wholegrain breads featured highly on the 'healthy' dietary pattern. Peas, mixed vegetables, potatoes, pumpkin, and beef featured on the 'traditional' dietary pattern. Wall and colleagues (2013) suggested regular evaluation of children's dietary patterns. They found that, as children get older, other factors such as maternal education become more important than demographics in children's food choices.

Cluster analysis

Cluster analysis is a statistical method, which clusters individuals into mutually exclusive groups according to the type of dietary pattern followed (Moeller et al., 2007). Participants in a cluster have similar diets and results are specific to individuals within each cluster and each cluster has discrepancies with the other clusters (Moeller et al., 2007). Therefore compare to factor analysis, cluster analysis results are easier to interpret (Newby, Muller, & Tucker, 2004).

Similar to factor analysis, this method demands a certain amount of subjective decisions such as which variables include, level of significance, and number of factors (Moeller et

al., 2007). For instance Emmett et al., (2015) collected data through FFQ and food records and used cluster analysis and factor analysis to identify the associations between dietary patterns and socio-economic status in children. Their results showed that children categorised into the 'health-conscious' pattern and 'traditional' pattern consumed more fruits and vegetables compared to those in the 'processed' pattern. They found that maternal education has an important role in the cluster grouping of children, with lower maternal education linked with higher scores on the 'processed' pattern (e.g. 'white bread, meat pies, sausages/burgers, fried foods, pizza, eggs, chips, roast potatoes, baked beans').

2-4-2. Theoretically derived dietary patterns

Diet quality indices

One of the dietary assessment methods used in epidemiological studies is dietary index (Kant, 1996, 2004; Michels & Schulze, 2005). Dietary indices are based on dietary guidelines (e.g. US dietary guidelines) (Moeller et al., 2007) or a particular dietary pattern (e.g. Mediterranean). A dietary index supplies a summary score (Waijers et al., 2007), which represents how close an individual's intake is to dietary guidelines and recommendations (McNaughton et al., 2008). Dietary indices are also known as 'dietary scores', 'diet quality indices' or 'healthy eating indices' among others (McNaughton et al., 2008). Dietary indices can measure diet quality (Bell et al., 2013). Compared to the other methods (e.g. factor analysis or cluster analysis), the most important advantage of dietary indices is that they are based on existing knowledge so can supply a clear nutritional standard, consequently they are easy to understand and interpret by clients and health specialists (Haines, Siega-Riz, & Popkin, 1999)..

Diet quality indices have different forms; food-based, nutrient-based, and a combination of nutrient and food-based (Kant, 1996). A diet quality index based on food relies on how many foods/food groups are consumed during a specific period time and then allocates scores according to variety and/or frequency of food consumption, regardless of the sources of nutrients (Kant, 1996; Ruel, 2003b). Food-based diet indices consider only food intakes, so they can score an individual or population's diet quickly however, they usually contain limited food options and so they may not completely represent diverse foods intakes. For example, some food items from a particular ethnic group may not be

included (Collins et al., 2015).

In comparison to nutrient-based indices, food-based dietary indices have several advantages. In clinical settings, research, and for education purposes, food-based diet indices are more preferable (Kant, 1996; Waijers et al., 2007). Furthermore, nutrient intakes and non-nutrient factors of foods can be assessed indirectly through food-based dietary indices, so they may be applied for follow up dietary intake approaches (McNaughton et al., 2008).

The evaluation of diet quality through dietary indices in children provides an opportunity to follow up food habits and behaviours during childhood in order to predict later risk of diet-related diseases (Rockett & Colditz, 1997). In the past, the main aim of nutritional studies was to determine adequate intakes of energy and nutrients for children, however, there is increasing recognition regarding the importance of diet quality and associations with general health (Moeller et al., 2007; Tucker, 2010).

Several studies have investigated associations between dietary indices, diet quality, chronic diseases (e.g. cancers and cardiovascular disease), and their outcomes among adults (Kant, 2004; Michels & Schulze, 2005). Despite this, in children, dietary indices and their relationships with risk factors for disease have been less considered (Lazarou & Newby, 2011). In children younger than five years old, 24-hour recall, food diary, or food record are usually used for dietary data collection (Smithers, Golley, Brazionis, & Lynch, 2011). However, these dietary assessment tools not only increase clients' burden but also their administration and analyses are expensive and time consuming (Magarey et al., 2011), therefore in epidemiological studies, applying these approaches can be a challenge. Although it is easy to assess energy and nutrient intakes through these dietary methods, it is usually difficult to compare dietary intake data, extracted from these methods, with dietary guidelines based on food intakes (Magarey, Golley, Spurrier, Goodwin, & Ong, 2009).

Application of diet quality indices

Dietary indices are simple, easy to apply, and relatively quick dietary assessment tools, therefore they can decrease researcher and participant burden, time and costs of data handling, so they are a suitable alternative method for data collection in nutritional

research and epidemiological studies (Bell et al., 2013). As an index can provide information about diet quality very quickly, they can be used as a short tool in clinical or fieldwork settings for the quick evaluation of children's and adults' dietary intakes against food recommendations and guidelines (Bell et al., 2013).

Diet quality indices do need to be developed for each country based on its common dietary patterns, recommendations, and nutritional guidelines (Bell et al., 2013; Collins et al., 2015). In developed countries, dietary indices for children generally aim to assess the diet quality and investigate the relationship between diet and disease risk factors (e.g. obesity). In comparison, in developing countries dietary indices in children are mainly designed to investigate associations between dietary adequacy, growth, and development (Marshall, Burrows, & Collins, 2014; Ruel, 2003a, 2003b).

Table 2-3. Types of dietary pattern analysis methods

Methods	Characteristics	Strengths	Limitations
Empirical methods (e.g. factor analysis and cluster analysis)	• Factor analysis - uses inter-correlations between food groups to determine dietary patterns. • Cluster analysis - clusters individuals into mutually exclusive groups according to the type of dietary pattern followed	• Factor analysis - Has greater statistical power than cluster analysis • Does not rely on a pre-defined definition for a healthy pattern	• High levels of subjectivity - variables depend on researcher's decision • Demands complicated statistical analysis and skills for analysing and interpreting • Does not reflect dietary guidelines
Theoretical methods (e.g. dietary indices)	• Supply a summary score, which represents how closely an individual follows dietary guidelines and recommendations • Show the general diet quality	• Based on existing knowledge so can supply a clear nutritional standard • Are easy to understand and interpret by clients and health specialists • Are cost effective • Have low burden for researcher and participant (depending on how data are collected)	• Need to be specified for each country • Rely on dietary guidelines selection • Rely on researcher's subjectivity

Note. Adapted from Moeller et al. (2007)

2-5. Previous research on diet quality indices

A number of dietary indices are available for use in both developed and developing countries. These will be discussed with a particular focus on three main dietary indices 'Diet Quality Index (DQI)', 'Healthy Eating Index (HEI)', and 'Mediterranean Diet Score (MDS)' and dietary indices that have been developed for use specifically in children.

2-5-1. An overview of original diet quality indices

Patterson et al., (1994) designed the first 'Diet Quality Index (DQI)' focused on foods/ nutrients (e.g. dietary fat) related to chronic diseases. The 1989 US national dietary recommendations were used for scoring individuals' intake and evaluating overall diet quality. Haines et al. (1999) revised the original DQI according to updated dietary guidelines and developed the 'Diet Quality Index Revised (R-DQI)'. The aim of this index was to follow up dietary changes in adult populations. In 2003, the 'Diet Quality Index-International (DQI-I)' was introduced for follow up of diet quality across different countries. Data from this study showed that the DQI-I is able to compare diet quality of Chinese and United States populations using two separate datasets, even though these two countries have different cultures and economies (Kim, Haines, Siega-Riz, & Popkin, 2003).

In 1995, the 'Healthy Diet Index (HEI)' was created by the US Department of Agriculture (USDA) (Kennedy, Ohls, Carlson, & Fleming, 1995), which is one of the most common dietary indices used. The HEI scores dietary intakes and measures quality of diet so it can follow up and evaluate adherence to American Dietary Guidelines based on American government recommendations for health maintenance and reduced risk of chronic disease (Guenther, Reedy, Krebs-Smith, & Reeve, 2008; Kennedy et al., 1995). In 2005, the HEI was revised and named the HEI-2005. The aim of this revision was to create a new tool to evaluate quality of the diet based on the 2005 American dietary guidelines recommendations (Guenther, Reedy, & Krebs-Smith, 2008). In 2010, HEI was updated according to dietary guidelines (US Department of Agriculture and US Department of Health and Human Services, 2010) and emphasis placed on the main aspects of diet quality including 'wholegrain, total fruit, whole fruit instead of fruit juice, total vegetables, greens and beans, dairy, total protein foods, fatty acids, seafood and plant proteins' and moderate consumption of refine grains, sodium, and added sugar (Guenther et al., 2014). Woodruff et al., (2010) updated the HEI according to

‘Canada’s new food guide recommendations’ and designed ‘Healthy Eating Index-C (HEI-C)’ for Canadian children.

The Mediterranean diet is characterised by a high intake of fruits, vegetables, whole grain cereals, legumes, and olive oil; a moderate intake of fish, dairy products; and low intakes of poultry and meat (Willett et al, 1995). The diet can also include moderate amounts of alcohol (predominantly from wine) drunk generally with meals (Willett et al., 1995). The ‘Mediterranean Diet Score (MDS)’ is an index, designed in order to evaluate adherence to the Mediterranean diet (Trichopoulou et al., 1995). This index originally was designed for adults but it has also been used for children (Marshall et al., 2014). The MDS has been applied to measure the link between qualities of the Mediterranean diet and health outcomes (Bach et al., 2006).

2-5-2. Diet quality indices developed internationally for children

A review of published studies from 1990 to 2016 was conducted focusing on dietary indices with these criteria: 1) designed for healthy child and adolescent population (2 to 18 years old), 2) designed according to national dietary recommendations and guidelines, 3) examined for validity and/or reliability, 4) food and/or nutrient based, 5) published in English.

A number of children’s diet quality indices have been developed in many countries such as the North American ‘Youth Healthy Eating Index (YHEI)’ (Feskanich, Rockett, & Colditz, 2004), the ‘Revised Children’s Diet Quality Index (RC-DQI)’ for American children (Kranz, Findeis, & Shrestha, 2008), the ‘Australian Child and Adolescent Recommended Foods Score (ACARFS)’ (Marshall et al., 2012), and the Greek ‘Preschool Diet-Lifestyle Index (PDL-Index)’ (Manios et al., 2010). Studies, which have validated diet quality indices are summarised in Table 2-4.

From 13 studies, five of the studies were carried out in either Australia or New Zealand. Some of the studies have adapted an original dietary index, such as the DQI (Manios et al., 2009; Vyncke et al., 2013), the HEI (Andrade, Previdelli, Marchioni, & Fisberg, 2013; Kyttala et al., 2014), or the Mediterranean diet adherences (Serra-Majem et al., 2009; Sotos-Prieto et al., 2015) and have tailored the original index to meet with their country specific dietary guidelines. For example Vyncke et al. (2013) adapted the DQI and designed the ‘Diet Quality Index for

Adolescents (DQI-A)' to evaluate the quality of diet of European adolescents. On the other hand Cheng et al. (2016) developed and validated a 'Chinese Children Dietary Index' from inception.

Some of these studies have examined only validity of these indices (Cheng, Duan, Kranz, Libuda, & Zhang, 2016; Kyttala et al., 2014; Manios et al., 2009; Serra-Majem et al., 2004; Sluik, Streppel, van Lee, Geelen, & Feskens, 2015; Sotos-Prieto et al., 2015; Vyncke et al., 2013) using dietary assessment questionnaires (e.g. food records, 24-hour recalls, and FFQ). Others tested the validity and reliability (Andrade et al., 2013; Branscum, Sharma, Kaye, & Succop, 2010; Hunsberger et al., 2013; Steele, Burns, & Whitaker, 2013; Wong, Parnell, Howe, Black, & Skidmore, 2013). A small number of studies have used biomarkers to evaluate validity of a dietary index (Roytio, Jaakkola, Hoppu, Poussa, & Laitinen, 2015; Vyncke et al., 2013).

2-5-3. Diet quality indices developed in Australia

Based on the Australian dietary guidelines for children, Burrows et al. (2014), Golley et al. (2011), and Marshall et al. (2012) developed diet quality indices for use in Australia. The purpose of these indices was to measure the quality of diet based on Australian dietary guidelines in children and adolescents.

Golley et al. (2011) developed and validated the 'Dietary Guideline Index for Children and Adolescents (DGI-CA)'. It consists of 11 components with possible score of 100. They analysed 3416 boys' and girls' data, aged between 4 to 16 years old. The mean of the index was 53.6 ± 0.4, which shows an average adherence of Australian children and adolescents towards dietary guidelines. Children with higher DGI-CA scores had a more healthy diet (lower intake of saturated fat, sugar, and sodium) compared to children who received a lower DGI-CA score. Variety, nutritious foods, and moderation in food consumption were considered in the design of this index. However, they used only two 24-hour recalls to validate the DGI-CA, which may not reflect habitual dietary intake for dietary data collection and validation.

The 'Australian Recommended Food Scores for Preschoolers (ARFS-P)' was developed by Burrows et al. (2014). The ARFS-P index was used for evaluation of diet quality among 142 Australian children, aged 2-5 years old. A food frequency questionnaire with 120 items was

used for validation of the ARFS-P. The total scores of diets ranged from 0 to 73. They examined the association between quality of the diet and food and nutrient intakes using linear regression analysis, and concluded that the ARFS-P was a valid tool for evaluating nutrient intakes in preschool children. Although they recruited enough participants to validate the tool, the sample population was from only rural locations, which decreases the generalisability of the results to the urban population.

Marshall et al. (2012) developed and validated the 'Australian Child and Adolescent Recommended Food Score (ACARFS)' in 691 children. This index was designed to evaluate the quality of diet based on food in Australian children and their adherence to the children and adolescents' dietary guidelines and recommendations. A food frequency questionnaire was used to derive the ACARFS. This index involved eight items including fruit, vegetables, proteins (meat and non-meat proteins foods), bread/cereals, dairy, water, and spreads/sauce, with a maximum total score of 73. Their findings suggested that the ACARFS has adequate accuracy for assessing food-based diet quality in children and adolescent. However, similar to the previous studies (Burrows et al., 2014; Golley et al., 2011) there is a chance of overestimation of child's diet quality and parental bias in dietary information.

2-5-4. Diet quality indices in New Zealand

There is only one published dietary index based on national dietary guidelines and recommendations in New Zealand for children and young people. Wong et al. (2013) designed the 'NZ Adolescent-specific Diet Quality Index (NZDQI-A)' and investigated its validity against four day food record (4DFR) and test-retest reliability in adolescents. They recruited 41 adolescents aged 14-18 years old. Participants' diets were scored from 0 to 100, with a lower score representing poorer quality of diet. Their results showed rational relative validity ($r = 0.39$) and reliability ($r = 0.65$) for the FFQ-derived NZDQI-A score.

Table 2-4. Overview of diet quality indices, which have been validated and/or tested reliability for children (n = 13 studies)

Author (year) country	Sample size, sex and age	Type of the study	Name of the index	Dietary methods to derive diet index	Type of test for validity	Number of components, components, and total score	Main results
OVERSEAS							
Serra-Majem et al. (2004) Spain	n = 3850 2-24 years old	Development and validation study	Mediterranean Diet Quality Index for children and adolescents (KIDMED)	•24-hour recalls • FFQ	•Biomarker •Dietary records	•Total component: 16 •Including: fruit, vegetables, fish, fast-food, pasta/rice, cereals/grains, nuts, olive oil, yoghurt/cheese, sweets/candy. •Total score: 12	•Average score: Did not measure •KIDMED index could evaluate the quality of Mediterranean dietary patterns in children and youth.
Manios et al., (2010) Greece	n = 2287 2-5 years old	Development and validation study	Preschoolers Diet-Lifestyle Index (PDL-Index)	•24-hour recalls •Food record	•24-hour recalls •Food record	•Total component: 11 •Including: fruit, vegetables, total grains, dairy, red meat, white meat/legumes, fish/seafood, unsaturated fats/sweet, physical activity, watching TV. •Total score: 44	•Average score: 18.2 •An inverse relation between the PDL-Index with being obese/overweight. •PDL-Index is a valid index.
Vyncke et al., (2013) study Ten European cities	n = 1804 12.5-17.5 years old	Validation study	Diet Quality Index for Adolescents (DQI-A)	•24-hour recalls	•Biomarker •24-hour recalls	•Total component: 9 •Including: water, bread and cereals, potatoes and grains, vegetables, fruits, milk products, cheese, meat/fish, fats and oils. •Total score: 100%	•Average score: 49 for males, 53.3 for females • DQI-A is a valid index • There was a positive corelation between the DQI-A scores and high nutrient content foods and an inverse correlation with high energy but low nutrient content food groups. • Vitamin D, vitamin B_{12}, and omega-3 fatty acid had direct relationship with the index scores.
Cheng et al., (2015) China	n = 1719 7-15 years old	Development and validation study	Chinese Children Dietary Index	•24-hour recalls	•24-hour recalls	•Total component: 16 •Including: grains, vegetables, fruits, dairy, soybeans, meat, fish/shrimp, eggs, drinking water, sugar sweetened beverages, vitamin A, fatty acids, dietary fibre, dietary variety, breakfast & dinner, energy balance. •Total score: 160	•Average score: 88.1 • The Chinese Children Dietary Index can successfully assess quality of diet Chinese children.
Sluik et al., (2015) Netherlands	n = 2106 7-69 years old	Development and validation study	Nutrient-Rich Food (NRF) index	•24-hour recalls	•24-hour recalls	•Total component: 15 •Including: physical activity, vegetables, fruits, fibre, fish, saturated fatty acids, trans-fatty acids, salt, alcohol, and consumption occasions. •Total score: 100	•Average score: Did not measure •The NRF index can provide information about quality of the diet.

Table 2-3. Continue

Author (year) country	Sample size, sex and age	Type of the study	Name of the index	Dietary methods	Type of test for validity	Number of components, components, and total score	Main results
OVERSEAS							
Andrade et al. (2013) Brazil	n = 2375 12 years and older	Evaluation of validity and reliability study	Brazilian Healthy Eating Index Revised (BHEI-R)	•24-hour recalls	•24-hour recalls	•Total component: 12 • Including: total fruit, vegetables, total grain, milk and dairy products, meat, egg, legumes, oils, saturated fat, sodium. •Total score: 100	•Average score: Did not measure •There was a weak correlation between the component scores and energy intake (r < 0.30). • The Cronbach α values showed internal consistency between the components (α = 0.7). BHEI-R is reliable and structurally valid.
Huybrechts et al. (2010) Belgium	n = 510 2·5-6·5 years old	Evaluation of validity and reliability study	Diet Quality Index for Preschool Children (DQI-CH)	•FFQ •Food diary	• Food diaries	•Total component: 4 • Including: beverages, bread/cereals, potatoes/grains, vegetables, fruit, milk, cheese, meat/poultry/fish, snacks, sugared drinks, fruit juice. •Total score: 100%	•Average score: 71 •DQI-CH is a valid and reliable tool which can be used to evaluate quality of the diet pre-schoolers.
Sotos-Prieto et al. (2014) Spain	n = 988 8-10 years old	Development and validation study	Mediterranean Lifestyle (MEDLIFE) index	•A semi-quantitative FFQ	•FFQ	•Total component: 28 • Including: food consumption (15 items), traditional Mediterranean dietary habits and physical activity (7 items), rest and social interaction habits (6 items). •Total score: 28	•Average MEDLIFE score: 11·3 •MEDLIFE is a short valid instrument.
Kyttälä et al. (2014) Finland	n = 1639 1, 3 and 6 years old	Development and relative validation study	Finnish Children Healthy Eating Index (FCHEI)	• Food records	•Food records	•Total component: 5 •Including: vegetables, fruit/berries, oil/margarine, high amount of sugar, fish/fish dishes, skimmed milk. •Total score: 34 (1-year-olds), 41 (3-year-olds), and 42 (6-year-olds).	•Average score: Did not measure •The FCHEI is a valid tool for identifying the diet quality of Finnish children's. •A higher FCHEI score reflects a healthier diet and the FCHEI can be considered a useful tool for describing the diet quality of pre-school aged children.

Table 2-3. Continue

Author (year) country	Sample size, sex and age	Type of study	Name of the index	Dietary methods	Type of test for validity	Number of components, components, and total score	Main results
AUSTRALIA							
Golley et al. (2011) Australia.	n = 3416 4-16 years old	Development and validation study	Dietary Guideline Index for Children and Adolescents (DGI-CA)	•24-hour recalls	•24-hour recall	•Total component: 11 •Including: dietary variety, fruit, vegetables, breads/cereals, meat, dairy foods, reduced-fat dairy, fluids, extra foods, healthy fats. •Total score: 100	•Average score: 60.6 (4-7-y old), 53.1 (8-11-y olds), and 48.6 (12-16-y olds) •The DGI-CA is a valid tool, which can evaluate the relationship between child diet quality and health outcomes.
Burrows et al. (2014) Australia	n = 142 4 years old	Validation study	Australian Recommended Food Scores for Preschoolers (ARFS-P)	•FFQ	•FFQ • Dietary information	•Total component: 8 •Including: vegetables, fruits, meat, meat alternatives (i.e. non- meat protein), breads/cereals, dairy, water, and condiments. •Total score: 73	•Average score: 36 •ARFS-P is a valid tool, which can evaluate nutrient intakes in children.
Marshall et al. (2012) Australia	n = 691 2-24 years old	Development and validation study	Australian Child and Adolescent Recommended Food Score (ACARFS)	• FFQ	•FFQ • Dietary information	•Total component: 8 •Including: fruit, vegetables, proteins, grains, dairy, water. •Total score: 73	•Average score: 25 •ACARFS has adequate accuracy for assessing food-based diet quality in children and adolescent.
NEW ZEALAND							
Wong et al. (2013) New Zealand	n = 41 14-18 years old	Development validation and reliability study	Diet Quality Index for NZ Adolescents (NZDQI-A)	•FFQ	•Food records	•Total component: 5 •Including: fruits, vegetables, grains, dairy products, meat. •Total score: 100	•Average score: 52.5 • The NZDQI-A is relatively valid and reliable index, which can rank diet quality of adolescents.

ACARFS = Australian Child and Adolescent Recommended Food Score, ARFS-P = Australian Recommended Food Scores for Preschoolers, BHEI-R = Brazilian Healthy Eating Index Revised, DGI-CA = Dietary Guideline Index for Children and Adolescents, DQI-A = Diet Quality Index for Adolescents, DQI-CH = Diet Quality Index for Preschool Children, FCHEI = Finnish Children Healthy Eating Index, FFQ = Food Frequency Questionnaire, KIDMED = Mediterranean Diet Quality Index for children and adolescents, MEDLIFE = Mediterranean Lifestyle index, n = number, NRF = Nutrient-Rich Food index, NZ = New Zealand, NZDQI-A = Diet Quality Index for NZ Adolescents, PDL-Index = Preschoolers Diet-Lifestyle Index.

2-6. Development of a diet quality index

In many countries, indices have been designed for adults, adolescents, and children. Dietary indices are relatively easy to do, and are a quick, low cost and low-burden instruments for assessing individuals' diet, therefore they can be a good alternative tool for collecting dietary data (Bell et al., 2013). There are a number of factors to consider when developing a diet quality index. These include the type and number of components, cut-off values and scoring for each component, and the total score.

2-7. Selection and type of index components

There are different types of dietary indices and the components, which comprise the index can be based on foods and foods group (Falciglia, Troyer, & Couch, 2004; Vereecken, Rossi, Giacchi, & Maes, 2008), nutrients (Fulgoni, Keast, & Drewnowski, 2009; Lambert et al., 2004), and foods and nutrients (Guenther et al., 2014; Kennedy et al., 1995; Patterson et al., 1994).

The number of dietary components can differ from a simple index with two components (e.g. saturated fat and fibre) (Biltoft-Jensen et al., 2008) to a complex index including 13 components, which considers food, nutrients, and behaviour (Kranz et al., 2006). Usually the selection of index components is based on national dietary guidelines or a particular dietary pattern (Waijers et al., 2007). National dietary guidelines are country-specific recommendations about the types/amounts of foods that should be consumed. The aim of these guidelines is to promote healthy lifestyles and decrease risk of chronic disease. They can be used by clinicians, policy makers, and food manufacturers (Marshall et al., 2012).

2-7-1. Foods and foods groups

The main food groups used in dietary indices are fruits and vegetables, cereals/grain, meat and meat products, meat alternatives (e.g. fish/nut/soya), and milk and milk products (Waijers et al., 2007). There is no doubt that adequate intakes of fruits and vegetables are important for good health. Some indices have combined fruits and vegetables and considered them as one component (Bazelmans et al., 2006; Kant, 1996; Patterson et al., 1994), while the others considered them as separate components since

they have such an important role in diet and health (Waijers et al., 2007). Compared to refined cereals, wholegrain are beneficial to health because they contain different micronutrients, antioxidants, fibre, phyto-oestrogens (in wheat bran), and beta-glucans (in oats) (Fung et al., 2002; Jensen et al., 2004; Liu, 2003). However, some indices such as the DQI (Patterson et al., 1994) or HEI (Kennedy et al., 1995) do not consider any differences between wholegrain and refined grains (Waijers et al., 2007). Since complex wholegrain contribute to decreased risk of diseases such as type II diabetes (Biltoft-Jensen et al., 2008), it has been suggested that wholegrain products are distinguished from refined cereals (Waijers et al., 2007). Milk and dairy products have been shown to increase children's bone health and decrease the risk of type II diabetes and obesity (Choi, Willett, Stampfer, Rimm, & Hu, 2005; Pereira et al., 2002; Zemel & Miller, 2004). However, whole fat dairy products contain saturated fatty acids (SFAs), so it is suggested that reduced milk and full-fat dairy products are considered when developing a dietary index (Waijers et al., 2007). Similar to milk components, Lee et al. (2008) included trimming fat off meat in their index scoring.

Deciding about some food components such as fruits, vegetables, bread, milk, and meat is more straightforward compared to other components such as nuts. In some indices including Mediterranean Diet Score (Trichopoulou et al., 1995) nuts are added to the fruits component and sometimes they are added to the legumes component (Waijers et al., 2007).

2-7-2. Macro- and Micronutrients

Common macronutrients such as total fat, saturated fatty acids (SFAs), trans fatty acids (TFAs), monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), complex carbohydrates, dietary fibre, and protein have been included in some indices (Waijers et al., 2007). For example, consumption of < 30% of total energy from fat is considered by the HEI (Kennedy et al., 1995) since a high intake of fat is associated with coronary heart disease (Hu, Manson, & Willett, 2001). Consumption of SFAs has been used as a single component in the DQI (Patterson et al., 1994) and HEI (Kennedy et al., 1995). Monounsaturated fatty acids (MUFAs) and PUFAs have been considered in the HEI-2010 (Healthy Eating Index 2010) because there is an association between higher

intakes of MUFAs and PUFAs and lower risk of cardiovascular disease (Bazelmans et al., 2006; Guasch-Ferre et al., 2015). Dietary fibre has been added to some indices (Kim et al., 2003) due to its association with reduced risk of coronary heart disease (CHD) and cancer (Kim & Je, 2016).

Micronutrients like sodium, calcium, iron, vitamin A, and vitamin C have been considered for indices scoring (Waijers et al., 2007). For instance, in the HEI, the recommended amount of sodium intake is < 2400 mg in order to obtain the highest score for this component (Wirt & Collins, 2009). In the DQI and its derivatives, calcium has also been considered (Patterson et al., 1994) but it is usually presented as a milk and milk products component.

2-7-3. Dietary variety

In order to have a healthy and balanced diet a wide variety of foods are recommended since one single food does not contain all the essential nutrients (Saibul et al., 2009). Therefore, some studies have added another component called 'dietary diversity' or 'dietary variety' (Haines et al., 1999; Harnack, Nicodemus, Jacobs, & Folsom, 2002; Kennedy et al., 1995), which is represented by either summing the number of foods eaten or the diversity within a specific food group across a given time (Saibul et al., 2009; Vereecken et al., 2008). There are different ways of determining dietary variety and it is usually based on researchers' decisions, as there is no international agreement. For example, Saibul et al. (2009) defined food variety as summing the number of foods consumed from a total of 69 food items across 3 days while Vereecken et al. (2008) calculated index variety as the total frequencies of 'fruits, vegetables, brown bread, whole fat, milk, semi-skimmed milk, cheese, and other milk products'. According to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' eating different types and colours of vegetables and fruits have been emphasised because eating fruits and vegetables from a range of different colours can ensure variety in the diet (Ministry of Health, 2012).

2-8. Cut-off values and scoring of index

Cut-off values and scoring methods, which are used for assessing diet quality, differ

across indices. Usually there are two different types of components-desirable components (e.g. fruits and vegetables) and undesirable components (e.g. sodium, sugar, and saturated fat) and they are scored in different ways in the scoring systems (Wirt & Collins, 2009). In general, desirable foods increase the diet quality and total score while undesirable foods act inversely. In order to determine cut-off points usually dietary guidelines (Harnack et al., 2002), recommended servings of main food groups (e.g. fruits, vegetables, bread, milk, and meat) (McNaughton et al., 2008), and the nutrient reference values are used (Patterson et al., 1994). However, the 'Mediterranean Diet Scores (MDS)' and its derivatives, use the median intake of each component as a cut-off point (Waijers et al., 2007).

There are different ways to select a cut-off point for each index item. The most straightforward method is to attribute one cut-off point for all index components (e.g. less than recommended level = 0 score and equal or higher than recommendation values = 1) (Waijers et al., 2007). Instead of just one cut-off value, some indices considered a minimum and maximum boundary for each component and then calculated an intermediate range proportionately (HEI, DQI-I) (Kennedy et al., 1995; Kim et al., 2003). In some indices such as the HEI-2010, all components have been converted to a percentage of total energy in order to score components (Guenther et al., 2014). In the 'Australian Recommended Food Score (ARFS)', consumption of each component ≥ once per week was awarded one point otherwise they scored 0 for no or < once per week consumption (Collins et al., 2015). To assess unhealthy eating behaviours, some indices penalise participants for overconsumption of undesirable foods (e.g. fat, processed meat) (Waijers et al., 2007). For instance, the 'Australian adults Diet Quality Index (Aussie-DQI)' considered a penalty point for overconsumption of fat, dairy products, meats and processed meat (Zarrin, Ibiebele, & Marks, 2013).

2-8-1. Contribution of the individual index items to the total score

The majority of indices gave the same weight to all individual components, which show they have equal contribution to the total score (Waijers et al., 2007). However, others such as the DQI-I, consider an unequal weighting system for different components (Kim et al., 2003). The plausible reason for different weights is that not all individual items

have an equal effect on our health. Therefore, higher weights are assigned to those components which have a greater effect on our diet quality and health (Waijers et al., 2007). For example, the 'Diet Quality Index for Preschoolers (RC-DQI)', awarded 10 points for consuming fruits and vegetables, while 5 and 2.5 points were allocated to linoleic acid (18_2) and linolenic acid (18_3) respectively (Kranz et al., 2006).

2-9. Validity and reliability of diet quality indices

Since there is a lack of a truly objective tool to measure individual's diet, different dietary assessment methods (e.g. FFQ) have been developed in order to collect dietary intake information (Willett, 1998). In nutrition assessment, the accuracy of information and correction of dietary data is a major challenge, which can affect the validity and reliability of the collected information (Bountziouka & Panagiotakos, 2010).

In nutritional research, validity means the ability of a dietary assessment method to measure dietary intakes and how close these measurements are to the actual (true) dietary intake values (Livingstone et al., 2004; Rose & Barker, 1978). Therefore when a method is considered as valid, the dietary intakes reported are not significantly different to actual dietary consumption (Livingstone et al., 2004) and there is a closeness between the test method and the accepted 'gold standard' method (Bountziouka & Panagiotakos, 2010). For evaluating the validity of nutritional assessment methods, it is usual that they are compared against another similar tool as an accepted 'gold standard' method (Livingstone et al., 2004) or they are compared with direct observation of dietary intakes (Baxter et al., 2006; Lytle et al., 1993; Weber et al., 2004). One of the most common dietary assessment methods, which is considered as a 'gold standard' method is the weighed food record since it does not rely on participants' memory (Rosilene et al., 2015).

Reliability refers to consistency and stability of measures after administration of the same questionnaire at different times to the same individuals (Kimberlin & Winterstein, 2008). 'Test–retest reliability or stability of measurement' evaluates the correlation and strength of the two sets of scores from a test (Kimberlin & Winterstein, 2008).

The interval time between first and second administration is important. Ideally, it should be long enough that the information given in the first administration does not affect the

second administration (due to the memory of a participant). On the other hand it should not be too long that changes in health status or learning affect the second time responses (Kimberlin & Winterstein, 2008).

2-9-1. Validity

Construct validity

Construct validity evaluates the correlation between index variables and the instrument. It examines whether a variable definition is able to show the actual theoretical meaning of a construct measured (Kimberlin & Winterstein, 2008). Also construct validity can judge the results from different studies, which have used the same instrument. For instance, it is expected that chronically ill patients have lower quality of life scores when compared with healthy college students. Therefore any correlation, which fits with this expected pattern contributes to construct validity (Kimberlin & Winterstein, 2008). It is common that construct validity is checked in indices studies, which are based on national dietary guidelines (Huybrechts et al., 2010; Newby et al., 2003). The accepted result is that a higher score associates with a better diet quality and more desirable dietary components. For example, within the dietary index developed for adolescents living in NZ it was expected that individuals with higher NZDQI-A scores, consumed more iron and lower total fat and saturated fat compared to individuals with lower NZDQI-A scores (Wong et al., 2013).

Content validity

Content validity (or rational validity or logical validity) examines whether the instrument adequately covers all aspects and every single element of content area (Kimberlin & Winterstein, 2008). Usually based on researchers' decisions and aims for selecting indices' components, content validity is used to check these components against dietary guidelines (Kimberlin & Winterstein, 2008).

Relative validity

Typically, relative (or criterion) validity is used in order to investigate how well a newly developed index and its scores ('test' dietary assessment method) agree with a standard

and independent dietary assessment method (‘reference’ dietary assessment method), which has a greater degree of validity (Rosilene et al., 2015). Relative validity has two different types: predictive and concurrent validity. Predictive validity is carried out when the researcher aims to predict a criterion measurement (Kimberlin & Winterstein, 2008). Concurrent validity is used when the researcher aims to score an index, which is correlated with another criterion measure (the gold standard measure) scored at the same time (Kimberlin & Winterstein, 2008). An example of such a situation is presented by Wong et al, (2013). They developed the NZDQI-A and compared the association between the NZDQI-A scores derived from FFQ (‘test’ instrument) with 4DFR (‘reference’ instrument) scores to assess relative validity.

2-9-2. Reliability

Reliability refers to the consistency of measures administered at two different occasions in the same population group or at the same time but in two different people (Kimberlin & Winterstein, 2008). There are four types of reliability: 1) Test–retest reliability or repeatability that measures the stability of a dietary method (the same standard), which is re-administered to the same individuals within a specified duration of time (Kimberlin & Winterstein, 2008; Lee-Han et al., 1989), 2) Inter-rater reliability, which uses the same instrument when taken by different individuals and aims to score different behaviour or events observed (Kimberlin & Winterstein, 2008; Lee-Han et al., 1989), 3) Inter-method reliability involves administration of different methods and measuring the same target from same individuals (Bountziouka & Panagiotakos, 2010), and 4) Internal consistency reliability, which considers the equivalence of results across items from the same test (Kimberlin & Winterstein, 2008).

2-10. Statistical analysis

Dietary indices need to be checked for validity and reliability using appropriate statistical techniques. There are different statistical methods for the assessment of the validity and reliability of dietary indices such as Pearson or Spearman’s correlation coefficients, paired t-test or Wilcoxin signed rank test, linear contrast analysis, linear regression

models, cross-classification, and Intra-class correlation coefficient (ICC) (Bountziouka & Panagiotakos, 2010).

Correlation coefficients (i.e. Pearson's r and Spearman's rho) have been used in many studies to assess relative validity (Bountziouka & Panagiotakos, 2010). Wong et al., (2013) used Pearson's correlation coefficients to evaluate the associations between the NZDQI-A scores relative to a 4DFR, and demonstrated fair agreement (r = 0.39) (Wong et al., 2013). Cross-classification analysis can find the percentages of participants categorized into the correct group or misclassified into the wrong group (Cade, Thompson, Burley, & Warm, 2002). When more than 50% of participants are classified into the same tertiles and less than 10% of participants are classified into the wrong/opposite tertiles, it means they are in the correct classification group level (Cade et al., 2002). For example, Wong et al., (2013) found that > 50% of the participants were categorised into the same tertile and < 10% were categorized into the opposite tertile.

Construct validity has been used to determine associations between the total indices scores and food and nutrient intakes (Kimberlin & Winterstein, 2008). For instance, Wong et al., (2013) found a significant correlation between higher NZDQI-A scores and higher consumption of iron, lower consumption of total fat, SFAs, and MUFAs. Pot et al., (2014) used Pearson's correlation coefficients (normally distributed data) to determine the correlation between the 'Eating Choices Index (ECI)' score with macronutrient and micronutrients intakes. Linear contrast analysis examines the indices scores capability to rank individuals based on their nutrient intakes across groups (Benitez-Arciniega et al., 2011). Usually the total score is considered as the continuous variable and divided into tertiles, then examined for its association with nutrient intakes (dependent variable) (Benitez-Arciniega et al., 2011).

One of the common methods for evaluating reliability in research is the Intra-class correlation coefficient (ICC) with Cronbach's alpha (Bravo & Potvin, 1991). Intra-class correlation coefficient (ICC) shows 'the degree to which two variable's movements are correlated' (Bland & Altman, 1999). Therefore, for investigating the relationship between the first administration and the second (test-retest reliability) the ICC is suggested (Shrout & Fleiss, 1979). One of the commonly used methods for assessing internal consistency of

multiple-item measurements, is Cronbach's alpha (Bountziouka & Panagiotakos, 2010). The Cronbach's alpha shows the degree of association between the items and so it gives us the overall measurement reliability (Bountziouka & Panagiotakos, 2010). The ICC has a range from 0 to 1, the higher amount representing higher reliability (Kimberlin & Winterstein, 2008).

Paired t-tests and the Wilcoxin signed rank test are another methods, which may be used to assess reliability. Paired t-tests (parametric data) and the Wilcoxin signed rank test (non-parametric data) compare means or medians of categorical variable respectively (Bingham et al., 1997; Cade et al., 2002; Collins et al., 2015). The Bland and Altman method can be used for assessing the agreement between a tested and standard method and calculating the bias between two methods. The Bland and Altman plot illustrates the difference between tested methods and the standard method against the mean of the two estimates (Bountziouka & Panagiotakos, 2010).

2-11. Summary

A relationship between unhealthy dietary intake of children and adolescents and some lifestyle-related diseases (e.g. overweight and obesity) has been shown by many research projects (Azadbakht et al., 2015; Gubbels et al., 2013; Magarey et al., 2011). In children, diet not only has an important role in growth, development, short- and long-term nutritional deficiencies/toxicities, but also acts as a modifiable component in many diseases such as heart disease, osteoporosis, cancer, blood pressure, and increased cholesterol levels (Kranz et al., 2006; Rockett & Colditz, 1997; Smithers et al., 2011). The consumption of high-quality foods and nutrients early in life can lead to optimal health later in life and decrease the chance of unhealthy lifestyle patterns and the development of chronic disease during adulthood (Kranz et al., 2006).

In both clinical and research settings, for evaluating dietary intakes, valid assessment tools are important for finding the link between dietary intake and disease (Wakai, 2009). There are different methods for collecting dietary intake data, including weighed or estimated food records, 24-hour recalls, food frequency questionnaire (FFQ), and the diet history (Lyu et al., 2014). Dietary patterns evaluate the effects of overall diet rather than single nutrients or foods and provide an alternative tool for identifying the associations

between diet and various health outcomes (Hu, 2002). Empirical methods such as factor analysis and cluster analysis and theoretical methods like diet quality indices or healthy eating indices are two different approaches for assessing dietary patterns (Newby & Tucker, 2004).

A diet quality index has been developed for adolescents in New Zealand (Wong et al., 2013) but not for children. Therefore, the aim of the current study was to examine the validity and reliability of the Dietary Index for a Child's Eating (DICE) among children aged 2 to 8 years. living in Auckland, New Zealand. We hypothesised that the first administration of the DICE would demonstrate both construct validity and relative validity. Our second hypothesis was that the DICE would be reliable, measuring by Intra-class correlation coefficient (ICC), with Cronbach's alpha and have internal consistency.

Chapter 3: Methods

3-1. Study design

The current study was a validation study. The 'Dietary Index for a Child's Eating (DICE)' study aims to assess the validity and reliability of a dietary index (DICE), which measures children's adherence to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)'.

3-2. Ethical approval

The study protocol was approved by the Human Ethics Committee of Massey University (Southern A; approval no. MUHECN14/023), and all caregivers provided written consent prior to participating in the study.

3-3. Participants

Caregivers (mothers) of children were recruited through an advertisement sent to potential participants on the Human Nutrition participant database at Massey University. Caregivers were considered as proxy reporters of their children's dietary intake. Caregivers of healthy children aged 2-8 years old whose children did not have any chronic diseases, and lived in New Zealand were eligible to participate.

3-4. Study procedures

Eligible participants received a study pack including an information sheet (Appendix A), consent form (Appendix B), a four-day estimated food record (4DFR) questionnaire (Appendix C), and the DICE Internet link (Appendix D). Participants completed the DICE online and returned their consent and 4DFR booklet in the post by pre-paid envelope. Eight weeks later participants were asked to complete the DICE for a second time.

3-4-1. DICE (Dietary Index for a Child's Eating)

All the participants received a SurveyMonkey link to the DICE questionnaire. The questionnaire consisted of 17 questions and took less than 10 minutes to complete. These questions were based on the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young people (Aged 2-18 years old)' (Ministry of Health, 2012). To assess the validity the first administration of the DICE data was used and compared with the

4DFR. Eight weeks after completing the first administration, participants were asked to repeat the same questionnaire to evaluate reliability.

3-4-2. Four day estimated food record (4DFR)

At the beginning of the study, written instructions about the 4DFR were posted to each participant. Written instructions were given on how to record all foods and beverages, which their children consumed during the recording days. The importance of precise information and following normal dietary habits during the study were explained. These instructions were also duplicated within the food diary.

Each participant completed a four day estimated food record (4DFR), including three continuous weekdays and one weekend day. All seven days of the week were covered across participants. Caregivers were asked to record the amount, brand names, recipe (ingredients of mixed dishes), food preparation methods, and the type of the food and drinks consumed. Portion size was estimated using household measures (e.g. cups, teaspoons, tablespoons), weights marked on food packages, and using comparisons (e.g. a spoon of ice cream equal to the size of a hen's egg). Caregivers were also asked to record the brand names and the amounts (e.g. tablets, drops or milliliters) of vitamin and mineral supplements their children used. Additionally, contact details for the researcher were provided and participants were advised to contact the researcher if they had any problems or queries about completing the food record. The food records were checked by trained researchers, who had a background in nutrition, and any incomplete information was followed up through emails to caregivers.

3-5. Overview of the New Zealand Food and Nutrition Guidelines for Healthy Children and Young people (Aged 2-18 years old)

Table 3-1 shows the New Zealand recommendations for children based on the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young people (Aged 2-18 years old)' (Ministry of Health, 2012). For designing the DICE components, scoring, and cut-off points, four statements from these guidelines were used. The statements from five to nine were not considered in this study. These guidelines are specific for the New Zealand population and are evidence-based therefore they provide a standard reference

for evaluating quality of diet.

Table 3-1. Food and nutrition guidelines for healthy children and young people (aged 2-18 years)[1]

Food and nutrition guidelines statements	Key features	Recommendation
1. Eat a variety of foods from each of the four major food groups each day	• Vegetables and fruit, including different colours and textures	• Intake of at least 2 serves/d of vegetables • Intake of at least 2 serves/d of fruit
	• Bread and cereals including wholegrain products as children increase in age	• Intake of at least 4 serves/d of breads and cereals
	• Milk and milk products or suitable alternatives, preferably reduced or low-fat options	• Intake of at least 2-3 serves/d of milk and milk products
	• Lean meat, poultry, fish, shellfish, eggs, legumes, nuts and seeds	• Intake of at least 1-2 serves/d of meat, poultry, seafood, eggs, and legumes, nuts and seeds
2. Eat enough for activity, growth and to maintain a healthy body size	• Eat regularly over the day, that is, have breakfast, lunch and dinner, and include in- between snacks for young children or if hungry	• Include regularly three meals and 2-3 snacks
3. Prepare foods or choose pre-pared foods, snacks, and drinks that are	• Low in fat, especially saturated fat.	• Intake occasionally only or less than once a week
	• Low in sugar, especially added sugar	• Intake occasionally only or less than once a week
	• Low in salt (if using salt, use iodised salt)	• Intake occasionally only or less than once a week
4. Drink plenty of water during the day. Include reduced or low-fat milk every day	• Limit drinks such as fruit juice, cordial, fruit drink, fizzy drinks (including diet drinks), sports drinks and sports water	• Intake occasionally only or less than once a week
	• Energy drinks or energy shots are not recommended for children or young people	• Energy drinks are not recommended
	• Do not give children less than 13 years of age coffee or tea. If young people (13 years and older) choose to drink coffee or tea, limit to one to two cups per day	• Drinking tea/coffee is not recommended
5. Alcohol is not recommended for children or young people	-	-
6. Eat meals with family as often as possible	-	• Try to have meals with family most/every day
7. Encourage children and young people to be involved in shopping, growing, and cooking family meals	-	• Try to involve children in shopping, growing, and cooking most/every day
8. Purchase, prepare, cook and store food in ways to ensure food safet	-	-
9. Be physically active	• Take part in regular physical activity, aiming for 60 minutes or more of moderate to vigorous activity each day. • Spend less than two hours a day (out of school time) in front of television, computers and gaming consoles. • Be active in as many ways as possible, for example, through play, cultural activities, dance, sport and recreation, jobs and going from place to place. • Be active with friends and whānau, at home, school, and in your community	• Do moderate to vigorous exercise at least 60 minutes per day • Do not spend more than 2 hours a day in front of TV, computers or gaming

[1] http://www.health.govt.nz/publication/food-and-nutrition-guidelines-healthy-children-and-young-people-aged-2-18-years-background-paper

3-6. Dietary Index for a Child's Eating (DICE) components, scoring, and cut-off points

In 2015, Hashimoto developed the DICE (Hashimoto, 2015), however prior to this validation taking place, some changes were made to the DICE components, food groups, their cut-off points, and scores. The DICE consists of 17 questions and it is scored from zero to 100, with a higher score representing increased adherence to these guidelines. The daily servings of main food groups including fruits, vegetables, milk products, meat/alternatives, bread and cereals are scored from 0 to 10 representing the importance of these food groups. Components' scores reflected the number of servings and contribution of each component in DICE's total score. The cut-offs, scoring, and details of each index components are shown in Table 3-2.

Fruit component

Fruit is considered a main food group as fruit contains energy, carbohydrate, fibre, vitamins (e.g. vitamin A, vitamin C, and folate) and minerals (e.g. potassium, magnesium), phytochemicals (e.g. flavonoids, phenols), and antioxidants (e.g. vitamin C) (Prior & Cao, 1999). Caregivers were asked to record the number of serves of fruit eaten every day. Fruit consumption was scored from 0 to 10 and the maximum score was given to participants consuming ≥ 2 servings of fruit daily. Participants scored 0, 2.5, 5, or 7.5 if they consumed 0, 0.5, 1, or 1.5 serves of fruit respectively.

Vegetable component

Vegetables are a main food group and provide energy, carbohydrate, fibre, vitamins (e.g. vitamin A, vitamin C, and folate) and minerals (e.g. potassium, magnesium), phytochemicals (e.g. lutein), and antioxidants (e.g. α-tocopherol). Starchy root vegetables provide carbohydrate and a high level of satiety (Ministry of Health, 2012). Participants were asked to record the number of vegetables eaten every day. Vegetables were scored from 0 to 10 and the maximum score was given to participants consuming ≥ 2 servings of vegetable daily. Participants scored 0, 2.5, 5, or 7.5 if they consumed 0, 0.5, 1, or 1.5 serves of vegetables respectively.

Variety component

The 'New Zealand Food and Nutrition Guidelines for Children and Young People (Aged

2-18 years)' have emphasised the importance of consuming a wide range of vegetables and fruit. Therefore, eating different types and colours of fruits and vegetables every day is recommended. The guidelines categorise fruits and vegetables' colours into five classes including: red (e.g. apple, berry, red capsicum, guava), yellow/orange (e.g. orange, apricot, carrot), green (e.g. lettuce, green pear), blue/purple (e.g. blueberry, red cabbage) or brown/white (e.g. mushroom, cauliflower). Eating different colours of fruits and vegetables is a good guide of dietary diversity (Ministry of Health, 2012), which can potentially enhance the quality of the diet. The variety of fruits was scored from 0 to 5, a maximum score given to participants consuming 5 different colours of fruits. Intermediate scores, 1, 2, 3, and 4, were given for one, two, three, and four different colours of fruits consumed respectively. Participants scored 0 if they did not report consuming any fruit. The same scoring system was applied for variety of vegetables.

Bread and cereals component

The bread and cereals section includes all kinds of 'breads, cereals, rice, pasta and foods made from grains'. They are considered as a main food group since they contain energy, carbohydrate, fibre, B vitamins and protein (Ministry of Health, 2012). Participants were asked to record the serves of bread and cereals consumed every day. Bread and cereals were scored from 0 to 10 and the maximum score was given to participants consuming ≥ 4 servings of bread and cereals daily. Intermediate scores were given to the lesser number of servings. Participants were scored 0, 2.5, 5, 7.5, or 10 if they consumed 0, 1, 2, 3, or ≥ 4 serves of bread and cereals daily.

Wholegrain component

The term of wholegrain does not have a universally accepted definition. Usually bran, germ and the endosperm, which are intact and contained in whole seeds, are considered to be wholegrain. This includes products such as 'whole wheat, whole-wheat flour, wheat flakes, bulgur wheat, whole and rolled oats, oatmeal, oat flakes, brown rice, whole rye and rye flour, whole barley and popcorn'. Wholegrain products contain fibre, vitamins (e.g. vitamin B) and minerals (e.g. magnesium, phosphorous) (Ministry of Health, 2012). Caregivers were asked to record how often they chose wholegrain products (never, rarely, sometimes, most days, and every day). The wholegrain component was scored from 0 to 5 and the maximum score was given to consuming wholegrain most or every day.

Participants scored 0 if they never or rarely consumed wholegrain products and they received 2.5 if they sometimes consumed wholegrain products.

Milk and milk products component

Milk and milk products (e.g. yoghurt, cheese) and alternatives (e.g. soy milk, fortified milk with vitamin D) are considered as a main food group since they contain energy, carbohydrate, protein, fat, vitamins (e.g. vitamin B, folate) and minerals (e.g. calcium, phosphorous). This component is very important for the optimal bone health of children. Reduced or low fat versions from this food group are the best choices because they contain less saturated fatty acids (SFAs) and often higher calcium levels (Ministry of Health, 2012). Participants were asked to record the number of serves of milk and milk products consumed every day. Milk and milk products were scored from 0 to 10 and the maximum score was given to participants consuming ≥ 3 serves per day. Participants received 0 if they consumed 0 serves, 2.5 for 0.5 and 1 serve, 5 for 1.5 serves, 7.5 for 2 and 2.5 serves, and 10 for ≥ 3 serves of milk and milk products per day.

Lean meat, poultry, seafood, eggs, legumes, nuts and seeds component

The meats and meats product component includes lean meat (e.g. beef, lamb), poultry (e.g. chicken), seafood (e.g. fish), eggs, legumes (e.g. peas and beans), nuts and seeds. They are considered as a main food group as they contain energy, protein, fat, vitamins (e.g. niacin, thiamin), and minerals (e.g. iron, zinc, selenium). Luncheon, salami, ham, bacon and sausages are considered as processed meats and limited intake is recommended (Ministry of Health, 2012). Participants were asked to record the number of serves of meat and meats products eaten every day. Meats and meats products were scored from 0 to 10 and the maximum score was given to consuming ≥ 1 serves per day. Participants were scored 0, 5, and 10 if they consumed 0, 0.5 or ≥ 1 serves respectively.

Number of meals and snacks components

The ‘New Zealand Food and Nutrition Guidelines for Children and Young People (Aged 2-18 years)’ recommend consuming three meals and two to three small snacks every day (Ministry of Health, 2012). It has been shown that there is a positive link between eating breakfast and health outcomes (e.g. optimal nutrient intake and normal body mass index) and also better cognitive function (e.g. memory, attention, and mood) of children and

young people (Ministry of Health, 2012). As children get older, they normally eat lunch at school therefore the school environment has an important role for encouraging healthy eating. Traditionally dinner is the meal, which members of most families have together (Ministry of Health, 2012). Consuming snacks (mini-meals) two times a day (in the morning and afternoon) are recommended (Ministry of Health, 2012). Healthy snacks can supply energy, protein, carbohydrate, vitamins, and minerals (Ministry of Health, 2012). A score of 5 was given when caregivers reported their child eating three or more meals or snacks most days or every day. A score of 0 was assigned when the child ate less than three meals and snacks per day, regardless of whether they were meals or snacks.

Prepared low fat foods, snack, and drink components

This component covers low fat foods, snacks, and drinks. Limited amounts of high fat foods and beverages are recommended since they contain high quantities of energy and low amount of nutrients and also contribute to overweight and obesity (Ministry of Health, 2012). A 5-points scoring system was used for this component when caregivers reported their child consuming low fat foods/snacks/drinks most or every day, and a 0 score was assigned for never or rarely consuming low fat foods/snacks/drinks. A score of 2.5-points scoring system was used when caregivers reported their child sometimes consuming these index components.

Prepared low salt foods, snack, and drink components

This component covers low salt foods, snacks, and drinks. Limited amounts of high salt foods are recommended since they contain low amounts of essential nutrients and there is a relationship between high intakes of salt and blood pressure (Ministry of Health, 2012). A 5-points scoring system was used for this component when caregivers reported their child consuming low salt foods/snacks/drinks most or every day, and a 0 score was assigned for never or rarely consuming low salt foods/snacks/drinks. A score of 2.5-points scoring system was used when caregivers reported their child sometimes consuming these index components.

Prepared low sugar foods, snack, and drink components

This component covers low sugar foods, snacks, and drinks. Limited amounts of high sugar foods and beverages are recommended since they contain high quantities of energy

and low levels of nutrients and also contribute to overweight and obesity (Ministry of Health, 2012). A 5-point scoring system was used for this component when caregivers reported their child consuming low sugar foods/snacks/drinks most or every day, and a 0 score was assigned for never or rarely consuming low sugar foods/snacks/drinks. A score of 2.5-points scoring system was used when caregivers reported their child sometimes consuming these index components.

Fluid and other drinks component

Fluid consumption was scored from 0 to 15. Participants could score a maximum of 15 points if only water and/or milk were consumed. If participants consumed only one serving of fruit juice or flavored milk alongside water or milk every day, they received 7.5 points, as consumption of these drinks in children should be limited (Ministry of Health, 2012). If participants consumed any other drinks such as cordial, fizzy drinks, sport drinks, tea or coffee they scored 0 points.

Table 3-2. Components of the DICE and scoring system

Components	Dietary guideline for NZ	Score range	Criteria for minimum score	Criteria for maximum score
Serve of fruits	Eat all fruits fresh, frozen canned, no-sugar-added fruit juice or dried fruit	0-10	0 serves/d	≥ 2 serves/d
Serve of vegetables	Eat all vegetables- fresh, frozen or canned	0-10	0 serves/d	≥ 2 serves/d
Variety of fruits	Eat many different colours of all fruits fresh, frozen canned, no-sugar-added fruit juice or dried fruit	0-5	Not consuming any colour	5 different colours
Variety of vegetables	Eat many different colours of all vegetables- fresh, frozen or canned	0-5	Not consuming any colour	5 different colours
Bread and cereals	Include all breads, cereals, rice, and pasta	0-10	0 serves/d	≥ 4 serves/d
Wholegrain products	Choose wholegrain versions of breads, cereals, rice, and pasta	0-5	Never	Most days & Every day
Milk and milk products	Include milks, yoghurts, cheeses and/or alternatives	0-10	0 serves/d	≥ 3 serves/d
Lean meat, poultry, seafood, eggs, legumes, nuts and seeds	Include lean meat, poultry, seafood, eggs, legumes (e.g. peas, beans, lentils), nuts and seeds (Limit processed meats)	0-10	0 serves/d	≥ 1 serves/d
Number of meals and snacks per day	Have breakfast, morning snacks, lunch, afternoon snacks, and dinner	0-5	< 3 meals or snacks/d	≥ 3 meals or snack/d
Prepare low fat foods, snacks, and drinks, especially saturated fat	Have low fat foods, snack, and drink	0-5	Never & rarely	Every day & most days
Prepare low salt foods, snacks, and drinks	Have low salt foods, snack, and drink	0-5	Never & rarely	Every day & most days
Prepare low sugar foods, snacks, and drinks	Have low sugar foods, snack, and drink	0-5	Never & rarely	Every day & most days
Fluid and other drinks	Drink plenty of water during per day and reduced or low fat milk every day Limit fruit juice, cordial, fizzy drinks, sports drinks, sports water, flavoured milk, Energy drinks are not recommended Do not give coffee or tea to children less than 13 years old	0-15	Other drinks - cordial, fizzy drinks, sport drinks, tea, coffee	Only water & milk ≥ 1 serve/d

3-7. Data handling and data analysis

3-7-1. DICE data handling and analysis

The SurveyMonkey data regarding the DICE questionnaire was transferred into an Excel spreadsheet and checked for missing data and matching ID numbers of participants with 4DFRs before being exported into statistical package for the social science (SPSS). The data was converted into DICE scores (see Table 3-2 for the decisions regarding the scoring of each component).

3-7-2. 4DFRs data handling and analysis

Converting 4DFRs into nutrient data

Trained researchers with a background in nutrition manually entered all the food records information into Foodworks (version 7, 2013, Xyris Software, Queensland). The Foodworks program is able to analyse dietary data and provide nutritional information about total energy, macronutrient, and micronutrient intakes. The 'New Zealand–Diet and Recipe Analysis (abridged) database' was chosen for food records entry. For consistency, the current thesis researcher checked all 4DFRs to ensure standardised assumptions and decisions were made across all food records. Foods were matched with a similar food when not available in the database (e.g. sprite zero was matched with soft diet drink). We calculated proportions of each ingredient for mixed dishes as well.

Converting 4DFRs data into DICE scoring system

All data from the 4DFRs was converted into the same components (e.g. number of serves of fruit, variety of vegetables, serving of wholegrain) as included in the DICE so the 4DFR could be scored similarly to the DICE. The same scoring systemas used for DICE was used for scoring the 4DFRs components. The amount of foods and beverages recorded by participants (e.g. 1 slice of bread, 1 medium size of apple), were used for calculating serving size of five main components (fruits, vegetables, breads/cereals, milk/milk products, and meat/alternatives). After calculating total number of servings for the 4 days, the average serve intake was obtained in order to get the most appropriate number of servings. If participants reported weight in grams/liter, these amounts were converted into serving sizes for each food item. For example 55 grams of muesli or 250

milliliters of milk were considered as one serving size (Ministry of Health, 2012). After calculating each component score, all the data were entered into SPSS for further analysis. All the assumptions and decisions for 4DFR components are shown in Appendix E.

The number of different colours of fruits and vegetables consumed over the 4 days were used for determining the variety of fruits and vegetables consumed respectively. If participants consumed wholegrain/whole meal products 3 (most days) or 4 days (every day) then they were scored 5 points.

According to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' definition, all products include 'whole wheat, whole-wheat flour, wheat flakes, bulgur wheat, whole and rolled oats, oatmeal, oat flakes, brown rice, whole rye and rye flour, whole barley and popcorn' are considered as a wholegrain component (Ministry of Health, 2012). If they consumed wholegrain/whole meal products only 2 (some days) out of 4 days, then they were scored 2.5 points. If participants consumed wholegrain/whole meal products on only 1 day (rarely) or they did not consume (never) from this food group, they scored 0 points.

Frequency of meals and snacks (mini-meals) were determined though calculating the number of meals and snacks per day. A score of 5 was given when three or more meals or snacks were consumed every day and if this was consistent over four days. A score of 0 was assigned when the child ate less than three meals or snacks per day, regardless of whether they were meals or snacks.

The amount of sugar, fat, and salt was calculated through Foodworks program in order to calculate the score of low fat, low salt, and low sugar foods, snacks, and drinks components. The 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' recommended that < 10% of total energy should be provided from saturated fatty acids (SFAs) (Ministry of Health, 2012) since SFAs lead to increase blood cholesterol levels and therefore increase the risk of heart disease (Liska, Cook, Wang, Gaine, & Baer, 2016). Therefore participants who consumed less than 10% of their total energy from SFAs received 5 points and participants who consumed ≥ 10% of total energy from SFAs scored 0 points. Total sugar was calculated using glucose, sucrose, and maltose. Fructose and lactose were excluded from this calculation. The

World Health Organisation (WHO) suggested limiting consuming sugar to 10% of their total energy (World Health Organisation, 2003a). In this study participants who consumed less than 10% of their total energy from sugar received 5 points and 0 points if they consumed ≥ 10% of total energy from sugar. According to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)', the adequate intake of sodium for children 2-3 years old is 200-400 mg and for 4-8 years old is 300-600 mg (Ministry of Health, 2012). If participants met these recommendations they scored 5 points otherwise they received 0 points.

All beverages consumed were considered over the four days. Fifteen points was given when only water and/or milk were recorded on the 4DFR. If participants consumed only one serving of fruit juice or flavoured milk alongside water or milk per day, they received 7.5, and if they consumed any other drinks such as cordial, fizzy drinks, sport drinks, tea or coffee they scored 0 points.

3-8. Statistical analysis

The computer software statistical package program SPSS version 22 was used to analyse the data (IBM corporation, New York, USA). The variables were tested for normality using the Kolmogorov-Smirnov (K-S) test and Shapiro-Wilk (S-W) tests and for homogeneity using the Levene's test. Descriptive statistics were applied for total scores and sub-scores from DICE, and 4DFR data. Our total scores were normally distributed so they were expressed as mean ± SD, for categorical data as a frequency (number (%)), and they were assessed by using parametric tests. However our sub-scores were not normally distributed and therefore non-parametric tests were applied for them.

Validity in this thesis was assessed by using different type of tests. The rational for using more than one approach to assess the same concept was that it can demonstrate the robustness of the validity process (Cade et al., 2002).

3-8-1. Relative validity

Total score

The relative validity of the first administration of the DICE total score with the 4DFR total scores was assessed by using Pearson correlation coefficient, cross-classification,

and weighted κ-statistic. A *P*-value less than 0.05 was considered significant. Cross-classification was used for total score in order to identify whether participants correctly were categorised into the same tertile by the index or if they were grossly misclassified into opposite tertile. Participants were correctly classified when more than 50% were allocated to the same tertile; when greater than 10% were allocated into opposite tertiles then misclassification was deemed to have occurred (Cade et al., 2002). For further investigation of agreement, two dietary assessment methods were checked using the kappa (κ) statistic using the following formula (Masson et al., 2003):

$\kappa = Pr(a) - Pr(e) / 1 - Pr(e)$

Pr(a) = relative observed agreement

Pr(e) = hypothetical probability of chance agreement

The following categories were used for describing the results of the kappa (κ) statistic; very good agreement if the value of $\kappa > 0.80$; good agreement if between 0.61 to 0.80; between 0.41 to 0.60 is considered moderate agreement; between 0.21 to 0.40 is fair agreement, and < 0.20 is poor agreement (Altman, 1991).

Index sub-scores

The Wilcoxon signed rank test was used due to test the differences between the first administration of DICE sub-scores for each component against the same component sub-score from 4DFR. Since the sub-scores data were not normally distributed, the Spearman rank correlation coefficient was used due to examine the relationship between individual's component sub-score from the first administration of DICE and the same component sub-score from 4DFR.

The following categories were used for describing the results of Spearman and Pearson's test; almost perfect if the value was between 0.9 to 1; very high if between 0.7 to 0.9; high if between 0.5 to 0.7; moderate if between 0.3 to 0.5; low if between 0.1 to 0.3, and insubstantial if between 0 to 0.1 (Hopkins, Marshall, Batterham, & Hanin, 2009).

3-8-2. Construct validity

The DICE (total score and individual components) were compared with energy and nutrient consumption extracted from the 4DFR to assess construct validity of the DICE.

Total energy, protein, carbohydrates, sugar, total fat, saturated fat, dietary fibre, vitamin C, vitamin A, vitamin D, folate, sodium, calcium, iron, and iodine were included in the analysis. The DICE total score and individual components were compared with nutrient intakes using the Spearman's rank correlation coefficient. Linear contrast analysis was used to compare nutrient intakes across the tertiles of DICE score. Polynomial contrast for nutrient intakes was used in order to calculate the *P*-value for the linear trend.

3-8-3. Reliability

Participants completed the DICE twice, with an interval of eight weeks to evaluate reliability. Intra-class correlation coefficients (Cronbach's α) were used to calculate the reliability of the two administrations of DICE. Intra-class correlation coefficient is classified as follows: Below 0.20 poor; 0.21-0.40 fair; 0.41-0.60 moderate; 0.61-0.80 substantial; and values 0.81-1 show perfect agreement (Field, 2009; Santos, 1999).

Chapter 4: Results

In this study the validity and reliability of the Dietary Index for a Child's Eating (DICE), designed to assess children's adherence to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' was investigated. The validity of the index was tested by comparing the DICE total and sub-component scores against the 4DFR total and sub-component scores. The reliability was tested by comparing the first and second administration of the DICE questionnaire.

We recruited 65 participants (29 boys and 36 girls), all of them completed DICE the first time, 63 completed the four day estimated food records (4DFRs), and 49 completed DICE for the second time, missing data were excluded for calculating validity and reliability respectively.

The mean ± SD of age in males were 4.1 ± 1.8 years and in females were 4.3 ± 1.7 years.

4-1. Dietary Index for a Child's Eating (DICE) Scores

4-1-1. Total scores of DICE

Table 4-1 shows the participants' total scores distribution in different categories, up to a maximum possible score of 100. A higher score represents greater adherence to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)'. The mean ± SD of DICE was 78.2 ± 11.5 (range = 47-100). Over seventy five percent of participants scored more than 70 points. These results show that the adherence of our participants to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' was moderate to high (Ministry of Health, 2012).

Table 4-1. Participants' distribution scores out of 100 according to DICE (n = 65)

DICE score	N (%)
< 49	1 (1.5)
50-59	4 (6.2)
60-69	11 (16.9)
70-79	13 (20.0)
80-89	23 (35.4)
≥ 90	13 (20.0)

Dietary Index for a Child's Eating (DICE)
N = Number, % = percentage

4-1-2. DICE component scores

The distribution of participants' frequency in each scoring category is shown in Table 4-2. The proportion of our participants achieving maximum scores were: fruit (75.4%), variety of fruit (86.2%), vegetables (50.8%), variety of vegetables (47.7%), bread and cereals (43.1%), wholegrain (67.7%), fluid (53.8%), meat/meat alternatives (81.5%), low salt foods/drinks/snacks (58.5%), low sugar foods/drinks/snacks (73.8%). All the children in this study ate at least three meals and/or snacks most days or every day. Most (67.7%) of the participants consumed 2-3 servings of milk per day. Nearly half of our participants (46.2%) never or rarely chose low fat foods/drinks/snacks.

In addition, Spearman correlation coefficients were undertaken using the total score and the individual sub-components from the DICE. Serving of fruits, serving of vegetables, variety of fruits and vegetables, wholegrain, milk and milk products, fluid intakes, and consuming low fat/sugar/salt foods/snacks/drinks were significantly correlated with the first administration of DICE total score at the $P < 0.01$ level (Table 4-2). However, bread/cereals and meat/meat alternatives did not correlate with total DICE score.

Table 4-2. Frequency of participants in each scoring group for DICE component sub-scores, and Spearman correlation of each index component with total score (n = 65)

DICE components	Criteria for scoring	DICE scores	Percent of participants in scoring group	Correlation with total score of DICE
Serving of fruits per day	0.5	2.5	3.1	0.322**
	1	5	4.6	
	1.5	7.5	16.9	
	≥ 2	10	75.4	
Fruit variety (number of different colours of fruit)	1	1	3.1	0.356**
	2	2	1.5	
	3	3	3.1	
	4	4	6.2	
	5	5	86.2	
Serving of vegetables per day	0.5	2.5	12.3	0.499**
	1	5	16.9	
	1.5	7.5	20.0	
	≥ 2	10	50.8	
Vegetable variety (number of different colours of vegetable)	1	1	1.5	0.470**
	2	2	4.6	
	3	3	10.8	
	4	4	35.4	
	5	5	47.7	
Serving of bread and cereals per day	1	2.5	3.1	0.223
	2	5	13.8	
	3	7.5	40.0	
	≥ 4	10	43.1	
Frequency of wholegrain products consumption	Never & rarely	0	9.2	0.424**
	Some days	2.5	23.1	
	Most & every day	5	67.7	
Serving of milk and milk products per day	0.5 - 1	2.5	23.1	0.454**
	1.5	5	9.2	
	2-2.5	7.5	49.2	
	≥ 3	10	18.5	

DICE components	Criteria for scoring	DICE scores	Percent of participants in scoring group	Correlation with total score of DICE
Serving of meat and its alternatives per day (e.g. Legumes, nuts, seeds, fish, seafood, eggs, poultry and red meat)	0.5	5	18.5	0.196
	≥1	10	81.5	
Number of meal and snacks	< 3 meals & snacks per day	0	0	-
	≥ 3 meals & snacks per day	5	100	
Fluid intake	> 1 serve of fruit juice and/or flavored milk or any other drinks	0	18.5	0.531**
	Water and/or milk and only 1 serve of fruit juice and/or flavored milk	7.5	27.7	
	Only water and/or milk	15	53.8	
Frequency of low fat foods/drinks/snacks intakes	Never & rarely	0	46.2	0.451**
	Some days	2.5	24.6	
	Most & every day	5	29.2	
Frequency of low salt foods/drinks/snacks intakes	Never & rarely	0	23.1	0.528**
	Some days	2.5	18.5	
	Most & every day	5	58.5	
Frequency of low sugar foods/drinks/snacks intakes	Never & rarely	0	7.7	0.452**
	Some days	2.5	18.5	
	Most & every day	5	73.8	

DICE = Dietary Index for a Child's Eating
** Correlation is significant at the $P < 0.01$ level (two-tailed)

4-2. Relative validity of DICE

4-2-1. Total score

The mean ± SD of DICE was 78.2 ± 11.5 and the 4DFR was 73.8 ± 10.8. Pearson correlation coefficient showed a significantly high correlation between the total scores for DICE and 4DFR (r = 0.72; $P < 0.001$). Results from cross-classification showed that more than 50% of our participants were correctly categorised into same tertile group of DICE and the 4DFR and less than 10% were misclassified in each tertile. The weighted κ-statistic results showed that the DICE total score and 4DFR total score had very good agreement (κ = 0.94).

Table 4-3. Pearson correlation and cross-classification between total DICE score and 4DFR score

	%CC	%GM	Weighted k-statistic	Correlation coefficients (*r*)	Correlation (*P*-value)
DICE total score & 4DFR total score tertiles	**61.9**	**6.3**	**0.94**	**-**	**-**
DICE total score & 4DFR total score	**-**	**-**	**-**	**0.72**	**< 0.001**

DICE = Dietary Index for a Child's Eating, 4DFR = Four day food records, % CC = Percent correctly classified, % GM = Percent grossly misclassified, Cross classification = (correctly classified: > 50% in same tertile, grossly misclassified: < 10% in opposite tertiles) Weighted κ-statistic = (very good agreement: k > 0.80, good agreement: 0.61-0.80, moderate agreement: 0.41-0.60, fair agreement: 0.21-0.40, and poor agreement: k < 0.20)

4-2-1. Index sub-components

The comparison between sub-scores for each component and total score from DICE with 4DFR is shown in Table 4-4. Each sub-component score from DICE was compared with same sub-component score from the 4DFR using Wilcoxon tests (Table 4-4). Serving of fruits and vegetables, wholegrain consumption, milk and milk products, and number of meals and snacks per day scores were not significantly different between the DICE and 4DFR using Wilcoxon test ($P > 0.05$). However, Wilcoxon tests results for variety of fruits, variety of vegetables, servings of bread and cereals, low salt foods/drinks/snacks, and low sugar foods/drinks/snacks from the DICE showed significantly higher scores compared to 4DFR scores ($P < 0.05$). In contrast, meat and its alternatives, low fat foods/drinks/snacks, and fluid consumption from DICE were significantly lower compared to 4DFR scores ($P < 0.05$) (Table 4-4).

Spearman's correlation coefficients showed significant positive moderate to high correlations (r = 0.44-0.96) results between the DICE and 4DFR for servings of fruit (r = 0.91), servings of vegetables (r = 0.96), variety of vegetables (r = 0.44), servings of bread and cereals (r = 0.85), consumption of wholegrain (r = 0.71), milk and milk products (r = 0.88), meat and its alternatives (r = 0.60), number of meals and snacks (r = 1), and fluid consumption (r = 0.61) ($P < 0.001$). A significant and inverse correlation was found for low fat foods/snacks/drinks (r = -0.30) consumption ($P < 0.05$) (Table 4-4). The variety of fruits, low salt foods/snacks/drinks, and low sugar foods/snacks/drinks components were not significantly correlated with the same components scores from the 4DFR.

Table 4-4. Comparison of sub-scores for each component and Spearman correlation coefficients and agreement between each component from first administration of DICE with the same component from 4DFR (n = 63)

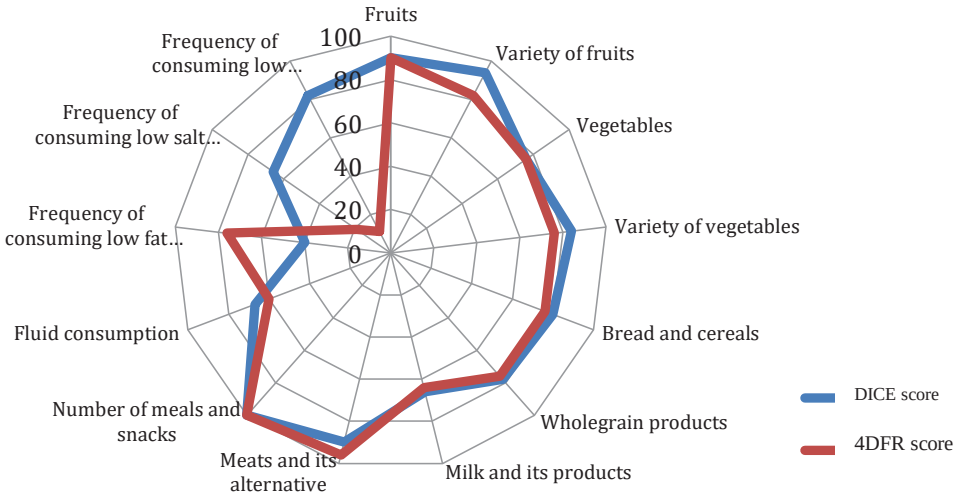
DICE components	Mean intake (serves/d) (DICE) [1]	Mean intake (serves/d) (4DFR) [1]	Mean difference (serves/d) (DICE & 4DFR)	DICE scores[1]	4DFR scores[1]	Differences between DICE scores and 4DFR scores	Wilcoxon test (*P*-value)	Correlation coefficients (r)	Correlation (*P*-value)
Servings of fruit	3.6 ± 0.7	2.0 ± 0.6	1.6	9.0 ±1.8	9.0 ±1.8	0	0.655	0.913	< 0.001
Variety of fruit	-	-	-	4.7 ± 0.8	4.1 ± 0.9	0.6	< 0.001	0.224	0.078
Servings of vegetables	3.0 ±1.0	1.5 ± 0.6	1.5	7.6 ± 2.7	7.6 ± 2.7	0	0.655	0.965	< 0.001
Variety of vegetables	-	-		4.2 ± 0.9	3.8 ± 0.8	0.4	0.004	0.440	< 0.001
Servings of bread and cereals	3.2 ± 0.8	3.1 ± 0.8	0.1	8.0 ± 2.0	7.6 ± 2.1	0.4	0.002	0.853	< 0.001
Servings of wholegrain products	-	-	-	3.9 ± 1.6	3.8 ± 1.6	0.1	0.796	0.712	< 0.001
Servings of milk and milk products	4.0 ± 1.7	1.8 ± 0.7	2.2	6.6 ± 2.5	6.4 ± 2.5	0.2	0.206	0.889	< 0.001
Servings of meat and its alternatives	2.6 ± 1.0	1.3 ± 0.5	1.3	9.0 ± 1.9	9.6 ± 1.3	-0.6	0.008	0.605	< 0.001
Number of meals and snacks	-	-	-	5.0 ± 0.0	5.0 ± 0.0	0	0.677	1	< 0.001
Frequency of consuming low fat foods, snacks, and drinks	-	-	-	2.0 ± 2.1	3.8 ± 2.0	-1.8	< 0.001	-0.300	0.017
Frequency of consuming low salt foods, snacks, and drinks	-	-	-	3.3 ±2.1	0.95 ± 1.9	2.3	< 0.001	0.191	0.134
Frequency of consuming low sugar foods, snacks, and drinks	-	-	-	4.1 ± 1.5	0.56 ± 1.5	3.5	0.001	-0.025	0.846
Fluid consumption	-	-	-	10.1 ±5.8	11.3 ±5.3	-1.2	0.047	0.611	< 0.001

DICE = Dietary Index for a Child's Eating, 4DFR = Four day food records

[1]Values represent mean ± SD

Figure 4-1 also shows the first administration of the DICE scores and 4DFR scores for each component.

Figure 4-1. The first administration of DICE scores and 4DFR scores



4-3. Construct validity of DICE

Spearman correlations between the DICE (total score and individual components), energy, and nutrients consumption extracted from the 4DFR are shown in Table 4-5. There was a significant positive relationship between the DICE total score and vitamin C (r = 0.53), folate (r = 0.45), and calcium intakes (r = 0.44) ($P < 0.001$). Servings of fruits were positively correlated with vitamin C (r = 0.30) and folic acid (r = 0.31) ($P < 0.05$). Fruit variety was significantly correlated vitamin C (r = 0.31). Serving of vegetables were inversely associated with energy (r = -0.23) and positively associated with vitamin C (r = 0.69) and folate intakes (r = 0.71). Vegetable variety and vitamin C (r = 0.38) and folate (r = 0.36) intakes showed significant positive correlations. Servings of bread and cereals were associated with total energy (r = 0.27), dietary fibre (r = 0.27), and iodine intakes (r = 0.70). Consumption of wholegrain products was correlated with energy (r = 0.38) and other nutrients including carbohydrate (r = 0.36), total fat (r = 0.39), saturated fat (0.38), and dietary fibre (r = 0.47). Milk and milk products correlated with calcium intakes (r = 0.86). There was a significant correlation between meat and meat alternatives with intake of iron (r = 0.50) and total fat (r =

-0.28). Low salt foods/snacks/drinks were inversely correlated with sodium (r = -0.26). Low fat foods/snacks/drinks did not show a significant correlation with total fat (r = -0.18) or saturated fat (r = -0.22). Also low sugar foods/snacks/drinks did not show any significant correlation with sugar (r = -0.28).

Table 4-5. Spearman correlations between the DICE (total score and individual components' score) with energy and nutrient intakes derived from the 4DFR (n = 65)

	DICE total score	Serving of fruits	Fruit variety	Serving of vegetables	Vegetables variety	Serving of bread and cereals	Whole grain consumption	Serving of milk and milk products	Serving of meat and its alternatives	Fluid consumption	Low fat foods/snacks/drinks consumption	Low salt foods/snacks/drinks consumption	Low sugar foods/snacks/drinks consumption
Energy (kcal)	0.05			-0.23*		0.27*	0.38**						
Protein (g)	-0.02								0.13				
Carbohydrate (g)	0.18						0.36**						
Sugar (g)	0.03												-0.28
Total fat (g)	-0.03						0.39**		-0.28*		-0.18		
Saturated fat (g)	0.05						0.38**				-0.22		
Dietary fibre (g)	0.20	0.03		0.04		0.27*	0.47**						
Vitamin C (mg)	0.53**	0.30*	0.31*	0.69**	0.38**								
Vitamin A (µg)	0.20	0.06	0.10	0.07	0.03								
Vitamin D (µg)	0.27												
Folate (μ g)	0.45**	0.31*	0.22	0.71**	0.36**								
Sodium (mg)	-0.00											-0.26*	
Calcium (mg)	0.44**							0.86**					
Iron (mg)	0.15								0.50**				
Iodine (µg)	-0.04					0.70**							

DICE = Dietary Index for a Child's Eating; 4DFR= Four day food record
*Correlation is significant at the 0.05 level (two-tailed)
** Correlation is significant at the 0.01 level (two-tailed)

Tertiles of the DICE total score and classification of energy and nutrients derived from the 4DFR in each tertile are shown in Table 4-6. Linear contrast analysis was used in order to compare nutrient intakes across the tertiles of the DICE score. Our results showed that higher intake of fibre, vitamin C, vitamin A, vitamin D, folate ($P < 0.05$), and calcium ($P < 0.001$) were associated with increasing tertile of the DICE total score.

Table 4-6. 4DFR dietary intakes categorized by tertiles of the DICE scores (n = 63)

Nutrients	**Tertiles of DICE scores**[1]			***P* -Trend**
	1 (n = 21)	**2 (n = 23)**	**3 (n = 19)**	
Energy (kcal)	1571.8 ± 297.4	1497.3 ± 240.1	1650.5 ± 257.9	0.186
Protein (g)	57.8 ± 7.0	58.4 ± 6.0	57.7 ± 7.7	0.934
Carbohydrate (g)	252.4 ± 21.3	256.0 ± 15.6	260.0 ± 19.1	0.442
Sugar (g)	91.7 ± 25.7	88.9 ± 18.8	94.0 ± 26.5	0.783
Total fat (g)	58.9 ± 15.0	56.0 ± 12.7	61.2 ± 11.5	0.446
Saturated fat (g)	29.8 ± 15.5	25.9 ± 11.5	33.2 ± 12.8	0212
Dietary fibre (g)	16.7 ± 3.0	18.9 ± 2.4	18.2 ± 2.8	0.039*
Vitamin C (mg)	30.4 ± 7.6	37.3 ± 14.8	39.1 ± 6.9	0.029*
Vitamin A (μ g)	487.0 ± 116.0	526.9 ± 90.7	574.1± 53.1	0.015*
Vitamin D (μ g)	2.1 ± 1.1	2.3 ± 1.2	3.2 ± 1.2	0.011*
Folate (μ g)	185.0 ± 37.8	203.6 ± 39.5	214.2 ± 34.9	0.052*
Sodium (mg)	866.2 ± 303.9	919.3 ± 358.9	861.2 ± 319.7	0.813
Calcium (mg)	569.1 ± 91.2	611.4 ± 85.9	686.8 ± 102.2	0.001**
Iron (mg)	9.7 ± 1.3	9.6 ± 1.2	10.2 ± 1.3	0.299
Iodine (μ g)	77.8 ± 10.1	76.7 ± 10.6	76.6 ± 8.2	0.920

DICE = Dietary Index for a Child's Eating; 4DFR = Four day food record
* Significantly different from tertile 1, $P < 0.05$ level (two-tailed)
** Significantly different from tertile 1, $P < 0.01$ level (two-tailed)
[1]Values represent mean ± SD

4-4. Reliability of DICE

The mean ± SD of the DICE at the beginning of the study and after eight weeks is shown in Table 4-7. Only 75% of our participants completed the DICE for second time. The Intra-class correlation coefficient was 0.87.

Table 4-7. Reliability of the DICE (n = 49)

Measurements	Mean ± SD	Cronbach's α	*P*-value[1]
DICE (at the beginning)	77.9 ± 11.3	0.87	< 0.001
DICE (after 8 weeks)	80.0 ± 12.5		

[1] *P*-value for Intra-class Correlation Coefficient

Chapter 5: Discussion and conclusion

To our knowledge there is currently no valid and/or reliable dietary index that can evaluate the adherence of children to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)'. Therefore, the Dietary Index for a Child's Eating (DICE) has been developed for healthy children aged 2 to 8 years old. The main objective of this study was to examine the relative and construct validity and reliability of the DICE in a group of 2-8 year-old children living in New Zealand (NZ). Our results demonstrated that the DICE has high correlation and very good agreement with a four day estimated food record (4DFR) total scores and almost perfect reliability. The relative validity results showed that servings of fruits and vegetables, wholegrain consumption, milk and milk products, and number of meals and snacks scores were not significantly different to the same components scores from the 4DFR. The construct validity results showed that there was a significant positive relationship between the DICE total score and dietary intakes of vitamin C, folate, and calcium. Participants, who were categorised into the higher tertile of DICE, consumed higher fibre, vitamin C, vitamin A, vitamin D, folate and calcium than those in lower tertiles. These results suggest that the DICE is a valid and reliable tool that may be utilised in research studies requiring assessment of diet quality in healthy children living in NZ. Overall, these results demonstrated that the DICE is able to give an accurate assessment of diet quality and has the potential to impose a low burden on participants and researchers compared to traditional dietary assessment methods.

5-1. Description of Dietary Index for a Child's Eating (DICE) scores

The maximum score of 100 for DICE would represent meeting all the recommendations for children from the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)'. Therefore, the higher the score on DICE the greater adherence is to current guidelines in NZ. The range of DICE total scores in this study was between 47 and 100, with a mean ± standard deviation (SD) total score of 78.2 ± 11.5. The wide range in total DICE scores from our study reflects the ability of the tool to determine a range of adherence to current guidelines.

Our participants met the maximum recommended servings for fruits, vegetables, bread and cereals, milk and milk products, meat and its alternatives as well as recommendations

for variety of fruit and vegetables, consumption of wholegrain, fluid intakes, and consumption of low salt and sugar foods/drinks/snacks. Although our participant group was self-selected, our results were similar to the '2008/09 National Survey of Children and Young People's Physical Activity and Dietary Behaviours in New Zealand' results (Clinical Trials Research Unit, 2010). For instance, according to that survey, 39.7 percent and 68.6 percent of children and young people (5-24 years old) met the vegetables and fruits recommendation respectively (Clinical Trials Research Unit, 2010). Our results showed that 50.8 percent and 75.4 percent of participants met 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' recommendations for consuming vegetables and fruits recommendation respectively. In that survey nearly half of participants (5-19 years old) ate brown/whole meal/wholegrain bread most of the time (Clinical Trials Research Unit, 2010) and more than half of our participants (67.7%) consumed wholegrain most of the time. It appears that perhaps our population group had a 'better diet' than 'average' and thus one might hypothesise that the caregivers in the current study may be more nutritionally aware, more educated and/or have higher income. Our results suggest that the DICE was able to reflect our participants' adherence to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' and that the majority of participants met the guidelines for servings of the main food groups and other dietary recommendations.

5-2. Relative validity (DICE vs. 4DFR)

Relative validity of the first DICE administration total scores and the four day estimated food record (4DFR) were examined by Pearson's correlation coefficients, cross-classification, and the weighted κ-statistic. Differences and correlations between the DICE component sub-scores with the same 4DFR component sub-scores were examined using Wilcoxon signed rank tests, and Spearman correlations coefficients respectively. The DICE results showed that there was a high correlation with the 4DFR ($r = 0.72$; $P < 0.001$) and very good agreement ($\kappa = 0.94$). Furthermore more than 50% of our participants were correctly categorised into the same tertile.

Similar to our study, previous studies have evaluated the relative validity and the correlation between diet index scores and a reference method (Collins et al., 2015;

Kyttala et al., 2014; Roytio et al., 2015; Wong et al., 2013).

Wong et al., (2013) examined the relative validity of the 'NZ Adolescent-specific Diet Quality Index (NZDQI-A)' (first administration) and a 4DFR, using Spearman's correlations coefficients. Kyttala et al., (2014) used correlation coefficients (Pearson and Spearman) to evaluate the agreement between the 'Finnish Children Healthy Eating Index (FCHEI)' total score and food record data.

It has been suggested that the index and the reference method need to have a correlation of at least 0.3 or 0.4 (Cade et al., 2002). In the present study, significant positive moderate to high correlations (r = 0.44-0.96) were found for DICE sub-scale components including servings of fruits and vegetables, variety of vegetables, servings of bread and cereals, consumption of wholegrain, servings of milk and milk products, servings of meat and its alternatives, number of meals and snacks, and fluid consumption. One possible explanation for moderate to high level of validity for these food items/groups is that our participants eat these food items frequently and therefore these regular habits cause this level of relative validity. In line with this, Wong et al., (2013) found correlations of more than 0.3 for most food groups, the highest relative validity was for cereals (r = 0.57) and the lowest for vegetables (r = 0.21). Similarly, in the 'Diet Quality Index for Adolescents (DQI-A)', recommended food items (e.g. fruits and vegetables) showed a positive correlation while a negative correlation was found for non-recommended food items (e.g. trans fatty acids) when compared with two, non-consecutive 24-hour recalls (Vyncke et al., 2013). Similar to our results, Collins et al., (2015) found that in the 'Australian Recommended Food Scores for Preschoolers (ARFS-P)' sub-scale scores for vegetables, fruits, meat, vegetarian alternatives, grains, and dairy were significantly positively correlated with dietary intake from a FFQ.

A significant and inverse correlation was found for low fat foods/snacks/drinks consumption between the 4DFR and the DICE (r = -0.30) and three sub-scores (variety of fruits, low salt foods/snacks/drinks, and low sugar foods/snacks/drinks components) were not significantly correlated with the same component scores from 4DFR. An explanation for these findings is the chance of overestimating of low salt and low sugar foods/snacks/drinks because of the design of the related questions and the pattern of the

parents' answers. Also there is a chance that parents are not aware, which foods/snacks/drinks are low salt and low sugar. It is recommended that the related questions require further clarification.

5-3. Construct validity of DICE

Index construct validity is an indicator of quality of a diet (Wong et al., 2013). In this study, correlations between the DICE scores and the 4DFR nutrient intakes were examined using correlation coefficients, which is comparable with the other validation studies methodology conducted in children and adolescents assessing construct validity (Andrade et al., 2013; Wong et al., 2013; Marshall et al., 2012).

There was a significant positive correlation between the DICE total score and 4DFR nutrient intakes such as vitamin C, folate, and calcium. However, Marshall et al., (2012) observed statistically significant positive correlations between the 'Australian Child and Adolescent Recommended Food Score (ACARFS)' and all vitamins and minerals which were tested. This may have been due to the larger sample (691 individuals) and older participants (9-12 years old) who were involved in their study. Similar to a previous study (Vyncke et al., 2013), we did not find a significant relationship between the DICE total score and the total fat and saturated fatty acids (SFAs) intakes. Moreover, the DICE total score did not show a correlation with energy intake. Andrade et al., (2013) found a weak relationship between the 'Brazilian Healthy Eating Index Revised (BHEI-R)' components' final score and total energy and suggested that these two variables are independent. This may explain the lack of correlation and indicate that DICE can evaluate the quality of the diet independently from energy intake.

Significant correlations between the DICE sub-scale components and nutrient intakes ranged from r = -0.28 (serving of meats and its alternatives and total fat) to r = 0.86 (milk and calcium). Servings of fruits were positively correlated with vitamin C and folic acid. Fruit variety was significantly correlated only with vitamin C. These results are related to the high concentration of these vitamins (vitamin C and folate) in fruit (Ministry of Health, 2012).

Vegetables are a rich source of fibre and micronutrients including vitamin C and folate.

Although vegetables are a source of carbohydrates they are not an energy dense food (Ministry of Health, 2012). As expected servings of vegetables were inversely associated with energy intakes and positively associated with vitamin C and folate intakes. Vegetable variety also showed a significant positive correlation with vitamin C and folate.

Bread and cereals contain energy, carbohydrate, fibre, B vitamins and protein (Ministry of Health, 2012). According to NZ government policy from 2009, most breads (with the exception of specialty breads) are mandatorily fortified (Ministry for Primary Industries, 2016) with iodine due to NZ's soil containing low levels of iodine (Skeaff, McLean, Mann, & Williams, 2013). Skeaff and Lonsdale-Cooper (2013) investigated the influence of mandatory fortification of bread with iodised salt among children (8-10 years old) living in NZ and found improved iodine levels (from 68 μg/l to 113 μg/l). Our results showed that servings of bread and cereals from DICE were significantly associated with dietary intakes of total energy, dietary fibre, and iodine.

Consumption of wholegrain products was correlated with energy and other nutrients including carbohydrate, total fat, saturated fat, and dietary fibre. The correlation between total fat and saturated fat with wholegrain could be due to most of our participants consuming margarine/spread and/or butter with wholegrain products as indicated by the food records.

The correlation between calcium intakes with milk and milk products was in the expected direction, which supports the fact that dairy products, which are recommended within 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' can promote optimal calcium intakes and the DICE was able to capture this concept.

Meat and its alternatives such as poultry, seafood, egg, legumes and nuts are source of energy, protein, carbohydrate, fats (usually saturated fat), minerals (e.g. iron, zinc), and vitamins (e.g. B_{12}) (Ministry of Health, 2012). Meat is a rich source of haem iron and our results showed that dietary iron intakes were positively associated with the consumption of meat and its alternatives. However, meat/meat alternatives showed a significant inverse association with the total fat (g) intake, which was an unexpected finding. The reason for this finding cannot be further explored, as there was insufficient detail within

the DICE questionnaire. Also there was no significant relationship between meat/meat alternatives and protein intake. One possible explanation for this finding is because so much protein is contributed by milk and milk products.

As expected low salt foods/snacks/drinks were significantly and inversely associated with intakes of sodium; and low fat foods/snacks/drinks and low sugar foods/snacks/drinks were inversely associated with total fat/SFAs and sugar intake respectively, but it was not significant.

Among studies, which have developed indices for children and adolescents (Andrade et al., 2013; Kyttala et al., 2014; Marshall et al., 2012; Wong et al., 2013), only a few have examined the construct validity of the index dividing their index's total score into quartiles (Kyttala et al., 2014) or tertiles (Wong et al., 2013) as a descriptor to indicate upper and lower ranges of diet quality. In the current study, participants were classified into tertiles based on their total DICE score in order to determine construct validity. As previous studies used different division (e.g. quartiles or tertiles) and statistical methods it was difficult to reasonably compare our results with other findings. However, most studies have found a positive relationship between higher index scores and more favourable nutrients (e.g. iron, calcium) (Kyttala et al., 2014) and inverse correlation with unfavourable nutrients (e.g. SFAs, sugar) (Marshall et al., 2012; Wong et al., 2013). When we compared nutrient intakes derived from the 4DFR against the upper tertile for the total DICE score, we found that participants in the highest tertile had higher intakes of dietary fibre, vitamin C, vitamin A, vitamin D, folate, and calcium. Consistent with our results, Wong et al., (2013) divided their index (NZDQI-A) total score into tertiles. They found a significant correlation between higher NZDQI-A scores and higher consumption of iron, lower consumption of total fat, SFAs and MUFAs. However, in our study, other macro- and micronutrients (e.g. protein, carbohydrate, sugar, sodium, iron) did not show any significant trend.

5-4. Reliability of DICE

The reliability of the DICE was tested using Intra-class correlation coefficient (ICC) between the first and subsequent administration of DICE. The ICC is considered the most common and useful method for evaluating reliability and determining the agreement

between repeated questionnaires (Bountziouka & Panagiotakos, 2010). Results from Cronbach's alpha for the DICE total score fell within the range of 0.81 to 1 (r = 0.87, indicating almost perfect agreement (Field, 2009; Santos, 1999). This finding suggests that the reliability of the DICE is excellent and therefore DICE is a reliable tool for evaluation the diet quality in NZ.

There are a number of indices, which have been designed for use in children (Cheng et al., 2016; Kyttala et al., 2014; Manios et al., 2009; Serra-Majem et al., 2004; Sluik et al., 2015; Sotos-Prieto et al., 2015; Vyncke et al., 2013) (Table 2-3) but very few of them have been examined the index reliability (Andrade et al., 2013; Branscum et al., 2010; Hunsberger et al., 2013; Steele et al., 2013; Wong et al., 2013). As there are some differences in previous studies' design such as the time interval between first and second administration, participants' age group, and sample size it is difficult to compare our reliability results with other studies. However, similar to our study Andrade et al., (2013) used Intra-class correlation coefficient to test the reliability of the 'Brazilian Healthy Eating Index Revised (BHEI-R)'. This study was done in a large sample group (n = 2,375) and older participants (boys and girls younger than 12 years old) and they found reasonable reproducibility (r = 0.7) for BHEI-R.

Consistent with our findings, Huybrechts et al. (2010) found similar results for reliability of the 'Diet Quality Index for Preschool Children (DQI-CH)' (r = 0.88). Their sample size was similar (58 individuals) as was the age group (2.5-6.5 years old). However, they only had a 5-week interval between the first and the second administration, compared to 8 weeks in our study.

5-5. Methodological issues

5-5-1. Index component, cut-off points, and scoring

There are different ways to select index dietary components, cut-off points, grouping of food items, and the scoring approach. Therefore, it is difficult to compare studies, which have used dietary quality indices even in similar population groups as the indices are developed and scored differently. There are no internationally recognised standards for developing indices and scoring systems that can measure diet quality.

Each component that makes up the total score for DICE refers to statements from the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' (Ministry of Health, 2012). However, there are some limitations regarding arbitrary decisions and assumptions, which may have misclassified participants and affected the total scores.

The DICE main food groups included fruits, vegetables, milk/dairy products, meat/alternatives, and bread/cereals. The recommended daily servings of each main food are considered for establishing cut-off values. Minimum and maximum boundaries for each component and an intermediate range were then proportionately calculated. Scores from 0 to 10 were assigned for the majority of components.

However, in some cases, establishing cut-off values for the DICE components was not straightforward. For example, there is no recommended daily serving for water intake (drink plenty of water is recommended) (Ministry of Health, 2012). The only other recommended fluid for children is plain cow's milk (or an alternative) therefore 15-points were assigned when only water or milk was consumed. If children reported only one serving of fruit juice or flavored milk with water/milk, they received 7.5 score because of the high energy density in those drinks (Vyncke et al., 2013) and limited intakes are recommended (Ministry of Health, 2012). When children consumed any other drinks, for example, cordial, fizzy drinks, sport drinks, tea, and coffee they scored 0 points since these beverages are not recommended for children (Ministry of Health, 2012), however, these children could still have been consuming milk and water.

There is no recommended daily serving for wholegrain products ('increase wholegrain products as children get older' is recommended) (Ministry of Health, 2012). In this case, participants scored 5 points when they consumed wholegrain products most or every day; 2.5 if they consumed wholegrain products sometimes and 0 if they never or rarely consumed wholegrain products. As these cut-off values were subjective and self-reported by caregivers, there is a chance of misclassification of participants. Clarification on the optimal intake of wholegrain within dietary guidelines would support the development and scoring of this aspect of a dietary index.

Two scores for diet varieties were added to the DICE since consumption of a variety of

coloured fruits and vegetables is recommended. Different types of fruits and vegetables can provide a wide range of nutrients and therefore enhance nutrient intake and diet quality (Waijers et al., 2007). According to the guidelines, fruit and vegetable colours are categorised into five groups including: red, yellow/orange, green, blue/purple or brown/white. One score was given to each colour group of fruits. Therefore the variety of fruits was scored from 0 to 5, with a maximum score given to participants consuming 5 different colours of fruits and the same scoring system was applied for variety of vegetables. However, there were some limitations in regards to these categories. For example, in this scoring system there is no difference between a participant who consumed only one type of green vegetable and a participant who consumed several different types of green vegetables (if they did not consume any other colours of vegetables), and in this case both of these participants received one point for the vegetable variety component. However, this is captured in the servings of vegetables component.

It is recommended that foods/snacks/drinks, which are high in fat, sugar, and salt should be limited to less than once a week (Ministry of Health, 2012). However, we asked how often our participants consume these components (never, rarely, some days, most days, and every day). In this case, 5-point was given when caregivers reported their child consuming low fat foods/snacks/drinks most or every day, a score of 2.5-points was assigned for sometimes and a 0 score was assigned for never or rarely consuming low fat foods/snacks/drinks. The same scoring system was applied for low salt and low sugar foods/snacks/drinks. A suggested amendment to DICE would be to include the number of servings per week for low fat/salt/sugar foods/snacks/drinks questions and to include serving sizes for these foods. These quantitative criteria could be considered for establishing cut-off values and therefore, the chance of misclassification would be decreased. Also it is recommended that the related questions should clarify the processed and non-processed foods/snacks/drinks. For example, if no processed foods are consumed, choosing low salt foods/snacks may not be applicable for some participants. Moreover there were some discrepancies in scoring system of these components between DICE and 4DFR results. Based on 4DFR data, ‘one cut-off value system’ (0 or 5 points) was considered for scoring low fat/sugar/salt foods/snacks/drinks. While same components

were scored in three levels (0, 2.5, and 5 points) which can increase the risk of misreporting.

Although the DICE scores reflect adherence to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)', collecting further details about foods (e.g. whether milk products were reduced fat or whether meat products were processed) may enhance the ability of DICE to accurately reflect diet quality. Advice on limiting servings of processed meats (e.g. luncheon, salami) is recommended in the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' but this is not captured in the current DICE tool.

Aspects of the current guidelines such as eating meals with family and frequency of child involvement in shopping/growing/cooking were not considered as part of DICE. It is suggested that they are added to DICE since these components are stated in the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)' (Ministry of Health, 2012). However, the validity of these components may be difficult to assess. Moreover, questions about physical activity and watching television/playing computer games could be added to the index since it has been shown that these behaviours correlate with diet quality (Kranz et al., 2006; Marshall et al., 2014).

Another difficulty is related to the weight of each component in relation to the total score. In this study, as in previous studies (Kranz et al., 2006; Wong et al., 2013), when assessing favourable (healthy) or unfavourable (unhealthy) components, a method of unequal weighting was assigned. A score of 10 was considered for main food groups including; fruits, vegetables, bread/cereals, milk and milk products, meat and its alternatives and the other components such as consumption of wholegrain received 5 points. However, the effects of equal or unequal weighting of each component within a diet index on our health are not clear (Woodruff & Hanning, 2010) and are worthy of further investigation.

5-5-2. Validation of the DICE

Selection of a reference method

To assess the ability of the DICE as an assessment method to measure dietary quality and confirm how close values from DICE were to actual (true) dietary intake values it was necessary to test for validity against a 'gold standard' (Bountziouka & Panagiotakos, 2010). Therefore in the absence of an absolute gold standard such as the doubly labeled water method and compared to the other dietary data collection (e.g. 24-hour recalls) the weighed food records are considered as an independent and acceptable reference method (Willett, 1998). Similar to previous studies (Rosilene et al., 2015; Wong, Parnell, Black, & Skidmore, 2012) we used the estimated food record rather than the weighed food record. Although it is more susceptible to errors (i.e. less than ideal) it may have improved the response rate due to less participant burden (Rosilene et al., 2015). It has previously been suggested that collecting 3-7 days food diaries would be enough for assessing food intakes (Willett, 1998). Each participant completed an estimated 4DFR; three continuous weekdays and one weekend day as it is well established that dietary habits could change at the weekends (Bingham et al., 1988). One advantage of using a food record is that it does not rely on participants' memory (Biro, Hulshof, Ovesen, & Amorim Cruz, 2002). Although it is a repetitive task and participants may reduce the number and types of different foods eaten (underreporting) to reduce the burden of recording, overall it is a fairly accurate method to measure food intake (Biro et al., 2002).

It is suggested that it is ideal if the 'test' and 'reference' cover the same period of time (Wong et al., 2012). In our study, participants completed the DICE first and then the 4DFR, which meant that the assessment did not cover the same period of time. This order of administration was chosen to reduce any influence that the reference method (4DFR) may have on the test method (DICE) as recommended by Gibson (2005).

Approaches to validation

The construct and relative validity of the DICE were tested in this study. Although there are some methodological issues (e.g. selection of a reference method) relating to the index construct validity, we found that the DICE is a valid and reliable index for

evaluating quality of diet and children's adherence to the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)'.

Biological markers are an independent method for assessing the relative validity of an index (James, Bingham, & Cole, 1981). This approach has become widely used since it has less inherent limitations such as misreporting but it is expensive and only a few nutrients have biomarkers (James et al., 1981). There are a number of studies, which have used biological biomarkers to validate dietary assessment methods (Fung et al., 2005; Hann, Rock, King, & Drewnowski, 2001) but very few of these have been undertaken in children (Roytio et al., 2015; Vyncke et al., 2013). Furthermore it would be difficult to accurately reflect overall diet quality with even a comprehensive range of biomarkers. In the current study we did not consider biomarkers due to its invasive nature and potential difficulties in obtaining parental consent.

5-6. Strengths and limitations

All the FoodWorks data was independently checked by trained nutritionists to increase the consistency and accuracy of the nutritional information. A very low proportion (3%) of our participants failed to complete the 4DFR.

Our participants were healthy children so, at this stage, the DICE can only be said to be valid and reliable when used in a similar population. Therefore, further validation studies are required before the DICE can be use in other populations. We recruited 65 participants, which is a good sample size, other experts have recommended sample sizes of at least 50 participants for validation studies (Cade, Burley, Warm, Thompson, & Margetts, 2004).

Our participants were children under eight years old. This age group may have limited cognitive abilities, and have difficulty evaluating portion size (Livingstone & Robson, 2000) therefore caregivers filled the questionnaires on behalf of their children (proxy reporters), which can increase a chance of parental bias (Burrows et al., 2014). Also there is a chance of misreporting since parents were not with their children at all times (e.g. daycare).

Furthermore our results were not adjusted for energy intake since the DICE score and

energy intake were poorly correlated (r = 0.05). We did not collect any other descriptive data such as height, weight, and information on ethnicity meaning we were unable to describe our study population in detail.

The major advantage of the DICE was that it was designed as a simple and short diet index, which makes it more convenient for health professionals to use and more understandable for caregivers.

5-7. Recommendation for further research

1) Revise the DICE questionnaire to assess aspects of diet quality such as healthy choices within the food groups and add more questions to the DICE in order to better reflect the 'New Zealand Food and Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)'. For example adding questions regarding type of milk and milk products (e.g. reduced fat), and clarifying difference between meat and processed meat.

2) Add the definition of "wholegrain products" and "snack" to the DICE related questions in order to make it more clearly for participants to answer.

3) Revise questions regarding to low fat/salt/sugar foods/snacks/drinks components. Adding number of servings per week for these components and including serving sizes to them is recommended.

4) Assess the relative validity of the DICE with the other validation methods (e.g. biomarkers) and adjust results for energy intake with a larger sample.

5) Conduct further studies to test validity of the DICE in different paediatric population groups (e.g. children with disabilities).

6) Conduct further research to investigate associations between dietary components and health indicators (e.g. body weight).

5-8. Conclusion

To our knowledge, the current study was the first study to evaluate a novel, stand-alone index of children's diet quality, the DICE, in New Zealand. Results from this study demonstrated that DICE is a valid and reliable tool for the assessment of children's adherence to a health-promoting diet, as recommended in the 'New Zealand Food and

Nutrition Guidelines for Healthy Children and Young People (Aged 2-18 years)'. Traditional methods such as FFQ, food recall, or food records, which have been used in dietary surveys, demand considerable efforts from participants as well as researchers in analysing the results. In some situations, for example, for public health intervention purposes, the overall diet quality is more important than the consumption of a single nutrient (Fransen & Ocke, 2008). According to our findings, the DICE is able to assess the diet quality and provide reasonably similar results to the 4DFR and reproducible data over an eight-week timespan for 2-8 year old children. Further research should be undertaken to refine the content and apply the DICE questionnaire to larger and different population groups.

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Appendix

Appendix A. Information sheet

The Healthy Eating Index study

Information sheet for study participants

Thank you for your interest in The Healthy Eating Index study. This sheet gives information on the conduct and organisation of this study, including confidentiality and data protection. It is important that you read this and are happy with the information given before agreeing to take part in the study.

We are currently recruiting 50 parents of children aged 2- 8 years and invite you to take part in this research. As a parent/guardian, it is important for you to understand why we are carrying out this research into the methods of assessing the dietary habits of children and what it will involve for you. This study will be conducted in a self-selected sample of parents of New Zealand children aged 2- 8 years. This information sheet tells you about the purpose of the study and what will happen to if you choose to take part. Please take time to read it carefully and discuss it with others if you wish. Please contact one of the researchers if there is anything that is not clear, or if you would like more information.

Assessing dietary intake in young children is problematic and can be a huge subject burden for parents. The current ideal or "Gold Standard" method is a four day weighed food record which is time consuming to complete. This method also relies on parents accurately weighing all the food presented to the child (as well as any leftovers) including each component of a meal and even providing recipes for mixed dishes. Therefore analysis of food records is often problematic due to the amount of detail and time required. The Children's Healthy Index Questionnaire (CHEI) has been developed to assess diet quality of children (based on New Zealand Food and Nutrition guidelines). The CHEI will allow researchers to understand what children are eating whilst reducing the time burden to participants.

What is the purpose of this study?

The purpose of this study is to develop a healthy eating index for young children (CHEI) and to validate this against a weighed food record. The reliability of the healthy eating index will also be tested by parents repeating the questionnaire used to create the healthy index score on two occasions 4-8 weeks apart.

Why have I been chosen?

You have been invited to participate because your child is between aged 2- 8 years old.

Do I have to take part?

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question;
- withdraw from the study at any time up until a month after completing the questionnaire.
- ask any questions about the study at any time during participation;
- provide information on the understanding that your name will not be used unless you give

permission to the researcher;

- be given access to a summary of the project findings when it is concluded.

What do I have to do?

You will be sent an email with a link to a healthy eating questionnaire. The questionnaire will take less than 10 minutes to complete. You do not have to answer any questions you are uncomfortable with, and you can opt out of the questionnaire at any time. The questionnaire incorporates questions about foods eaten, serving sizes and eating habits.

You will also be asked to complete a food diary for a duration of four day. You will need to include what your child ate and drank, where they ate, the quantity of the food or drink and how it was prepared/ cooked. You will be provided with detailed instructions on how to estimate the food and drink. The completion of the food diary will take approximately 10 minutes per day. We will ask you to return the food diary in a pre-paid envelope. A researcher will contact you if clarification is needed regarding the foods in the diary.

Four to eight weeks after completing the healthy eating questionnaire you will be asked to repeat the same questionnaire to allow us to test the reliability of the healthy index score**.**

What discomfort (physical, psychological, social), incapacity or other risk of harm are individual participants likely to experience as a result of participation?

There is the potential that parents will be more concerned about feeding their child after completing the questionnaire and food diary.

Will I be reimbursed for my time?

To thank you for your participation you will receive a gift pack containing various educational and useful resources. On completion of the questionnaire you will also be directed to a web page (hosted on the Massey Paediatric Infant Feeding and Nutrition (PIFaN) website) which will provide information about dietary guidelines, and how to seek help if you have a child with feeding issues.

Will my taking part in the study be kept confidential?

Yes. All information collected about you during the study will be kept strictly confidential. Information will be entered into a protected database at Massey University. Massey University codes all data so that your name and address cannot be identified from the study data.

Information collected about you will be kept strictly confidential and secure in locked filing cabinets and/or electronic files on computers with passwords and restricted access. Each participant is assigned a unique anonymising code which is used on all data collected. Only the specified research team will have access to personal identifying information.

Once we have finished the study and analysed the data, the spreadsheet containing all the responses will be archived and securely stored for five years.

What will happen to the results?

The findings of the study are available to you, so we will be posting a summary of the findings on our website around the end of 2014. Bookmark this page (http://www.massey.ac.nz/pifan_home.cfm) and visit it for updates on the study.

Who is organising and funding the study?

This study is part of a research programme conducted by the Paediatric Feeding and Nutrition Centre (PIFAN), College of Health, Massey University. The study is co-ordinated by Owen Mugridge.

Who has reviewed the study?

This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application 14/023. If you have any concerns about the conduct of this research, please contact Dr Lily George, Acting Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800 x 43279 email humanethicsnorth@massey.ac.nz

Contact for further information

If you have any further questions or if you have any concerns whilst participating in the study then please contact Owen Mugridge – 09 414 0800 Ext 43650.

Massey University, Albany

College of Health

Gate 4 – Building 80 Turitea Place Albany 0632 Auckland

Fellow researchers:

Dr Pam von Hurst

Dr Cath Conlon

Dr Kathryn Beck

Appendix B. Consent form

Institute of Food, Nutrition and Human Health
Massey University
Private Bag 102-904
North Shore Mail Centre
Albany, Auckland
New Zealand

T 09 414 0800
F 09 443 9640

An investigation of risk factors for vitamin D deficiency during pregnancy and infancy in Afghani women and their newborn infants

PARTICIPANT CONSENT FORM

This consent form will be held for a period of five (5) years

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: ..... **Date:** .....

Full Name - printed

Appendix C. Four day food record

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

The Healthy Eating Index study

4 Day Food Record

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

If you have any questions, please contact Owen Mugridge on (09) 414 0800 Ext 43650 or email o.mugridge@massey.ac.nz

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

4 day food diary - what to do?

- Record all of the food that your child eats and drinks on the following dates:

  Consecutive days for 1 weekend day and 3 week days. For example, Sunday, Monday, Tuesday and Wednesday OR Wednesday, Thursday, Friday and Saturday.

-
- 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.

- If possible, please bring any supplements your child is currently on

- You can also save any packets such as muesli bar wrappers and bring them in with your child's food diary

- Please answer the short questionnaire at the back of this booklet regarding your child's diet

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	2 Weetbix (homebrand) 1 cup Pam's whole milk 1 tsp Chelsea white sugar
Lunch – Ham sandwich	2 slices of wholegrain bread (vogels) 1 slice ham 2 slices edam cheese Water 1 cup to drink Sandwich spread
Dinner – Spaghetti Bolognese	½ cup mince sauce (see attached recipe) 1 cup spaghetti pasta (homebrand) Milk 1 cup Pam's whole milk
Snacks	Flemmings apricot chocolate chip muesli bar (35g) 1 small banana 2 Salada crackers with 1 tsp peanut butter

- 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 white fish pan-fried

- 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/ Fish	½ cup of casserole minced beef or 2 breaded fish fingers

Vegetables	½ cup cooked mixed vegetables (Wattie's peas, corn, carrots)

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

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

General description	**Food record description**
Milo	I x cup Milo made with Milo powder and 150 mls Calcitrim milk, 100 ml hot water. No sugar

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

Recording the amounts of food your child eats

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 – e.g. a 425g tin of baked beans, a 32g cereal bar,

- 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 (e.g. sandwich, medium, toast) – also include brand and variety.

- Using comparisons – e.g. 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 best describe portion sizes throughout the rest of the diary.

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

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

- ***Please try to have your child eat as normally as possible – ie. Don't adjust what he/she normally eats just because you are keeping a diet record and be honest! This record will give us important information about your child's diet, and help us identify any possible deficiencies which we can then help you correct.***

Example day

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

Date_____ **DAY 1**

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

Date_____ DAY 1 continued

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

Recipes (Day 1)

Recipes (Day 2)

Date_____ **DAY 2**

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

Date_____ **DAY 2 continued**

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

Date_____ DAY 3

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

Date_____ DAY 3 continued

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

Recipes (Day 3)

Recipes (Day 4)

Date_____ **DAY 4**

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

Date_____ **DAY 4 continued**

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

Date_____ (spare pages)

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

Date_____ (spare pages)

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

Appendix D. Dietary Index for a Child's Eating (DICE)

Instructions for completing the questionnaire

Thank you for taking part in our study looking at healthy eating in preschool children in New Zealand.

There are no right or wrong answers. You do not have to answer any questions you are uncomfortable with, and you can opt out of the questionnaire at any time.

The questionnaire will take less than 10 minutes

to complete. Please contact us if you would like

any help or more information.

Researcher: Owen Mugridge email:
o.mugridge@massey.ac.nz phone: 09 414 0800
Researcher: Dr Cath Conlon email:
c.conlon@massey.ac.nz phone: 09-414-0800
ext: 41206
Researcher: Dr Pam von Hurst email:
p.r.vonhurst@massey.ac.nz phone: 09-414-0800
ext: 41205
Researcher: Dr Kathryn Beck email:
k.l.beck@massey.ac.nz phone: 09-414-0800
ext: 41210
This project has been reviewed and approved by the Massey University Human Ethics Committee: Northern, Application XX/XX. If you have any concerns about the conduct of this research, please contact Dr Andrew Chrystall, Acting Chair, Massey University Human Ethics Committee: Northern, telephone 09 414 0800 x 43317 email humanethicsnorth@massey.ac.nz

1. What is your child's unique ID code? (Note: this number is written on the food diary enclosed in the study packi.e. HEI____)

2. What is your child's date of birth?

WHAT DOES A "SERVING" LOOK LIK

We see a lot of information about "servings" in nutrition advice and on food packaging. If you've ever wondered what a "serving" of a particular food looks like, here's a guide to help you. These are the recommendations from the Ministry of Health for the main food groups. The playing cards are there to give you an idea of the size of each item.

FRUIT

at least 2 A DAY

VEGETABLES

at least 3 A DAY

MILK, YOGHURT, CHEESE

at least 2 A DAY

BREAD, CEREAL, RICE, PASTA, NOODLES

at least 6 A DAY

OILS AND FATS

MEAT, POULTRY, FISH, EGGS, LEGUMES

WATER AND OTHER FLUIDS

3. How many servings of fruit does your child eat each day?

Examples of servings are:

- 1 apple, pear, banana or orange
- 2 small apricots or plums
- ½ cup of fresh fruit salad
- ½ cup of stewed or canned fruit

- none
- ½ servings
- 1 serving
- 1 and ½ serving
- 2 serving or more

4. How many servings of vegetables does your child eat each day?

Examples of servings are:

- 1 medium potato, taro or kūmara
- ½ cup of cooked vegetables
- ½ cup of salad
- 1 tomato

- none
- none
- ½ servings
- 1 serving
- no
- 1 and ½ serving
- 2 serving or more

5. Fruits come in many different colours. How many different types does your child eat from the following colour groups?

	0	1	2	3	4	more types
Red fruits (eg: red apples, cherries, red grapes, strawberries, watermelon)	○	○	○	○	○	○
Orange/yellow fruits (eg: yellow apples, apricots, oranges, mandarins, peaches)	○	○	○	○	○	○
Green fruits (eg: green apples, green grapes, kiwi fruit)	○	○	○	○	○	○
Blue/purple fruits (eg: blackberries, blueberries, plums, purple grapes, raisins)	○	○	○	○	○	○
White fruits (eg: bananas)	○	○	○	○	○	○

6. **Vegetables come in many different colours. How many different types does your child eat from the following colour groups?**

	0	1	2	3	4	5 or more types
Red vegetables (eg: red potatoes, red capsicums, tomatoes, yams)	○	○	○	○	○	○
Orange and yellow vegetables (eg: carrots, pumpkin, sweet corn, gold or orange kumara)	○	○	○	○	○	○
Green vegetables (eg: avocados, green beans, broccoli, green cabbage, cucumber, peas, spinach, puha, watercress, kamokamo, bok choi)	○	○	○	○	○	○
Blue/purple vegetables (eg: eggplant, red cabbage)	○	○	○	○	○	○
White vegetables (eg: cauliflower, mushrooms, onions, parsnips, potatoes, taro, cassava, breadfruit)	○	○	○	○	○	○

7. **How many servings of bread and cereals does your child eat each day?**

Examples of servings are:

- **1 roll**
- **1 medium slice of bread**
- **1 medium slice of rēwena bread**
- **1 cup of cornflakes or rice bubbles or 2 breakfast wheat biscuits**
- **½ cup of cooked cereal (eg: porridge)**
- **1 cup of cooked pasta, noodles or rice**
- **1 cup of cassava or tapioca**
- **2 plain sweet biscuits**

- none
- 1 servings
- 2 serving
- 3 serving
- 4 serving or more

8. **How often does your child eat wholegrain versions of these foods?**

- never
- rarely
- some days
- most days
- every day

9. **How many servings of milk, milk products and calcium-fortified milk alternatives does your child eat each day?**

Examples of servings are:

• 1 cup of reduced- or low-fat milk
• 1 pottle of reduced- or low-fat yoghurt
• 2 slices or ½ cup of grated cheese (eg: edam)

- none
- ½ servings
- 1 serving
- 1 and ½ serving
- 2 serving or more
- 2 and ½ serving
- 3 serving or more

10. **How many servings of meats, chicken, seafood, eggs, legumes, nuts and seeds does your child eat each day?**

Examples of servings are:

• 2 slices of cooked lean meat (eg: roast lamb, chicken, beef or pork)
• ¾ cup of mince or casserole
• 1 medium fillet of fish or steak
• 2 chicken drumsticks or 1 chicken leg
• 1 medium pāua or kina
• 1 egg
• ¾ cup of cooked dried beans (eg: baked beans)
• 1/3 cup of nuts or seeds

• ¾cup of tofu

- none
- ½ servings
- 1 serving
- 1 and ½ serving
- 2 serving or more

11. Please tell us about any cultural or traditional foods which are important to your child

12. Does your child eat

	Never	Rarely	Some days	Most days	Every day
Breakfast	○	○	○	○	○
Mid morning snack	○	○	○	○	○
Lunch	○	○	○	○	○
Mid afternoon snack	○	○	○	○	○
Dinner	○	○	○	○	○

13. How often do you choose low fat food, snack and drink options for your child?

- never
- rarely
- some days
- most days
- every day

14. How often do you choose low salt food, snack and drink options for your child?

- never
- rarely
- some days
- most days
- every day

15. Howoften do you choose low sugar food,snackanddrinkoptionsforyourchild?

- never
- rarely
- some days
- most days
- every day

16. Is your child

- vegetarian
- vegan

17. How many cups/glasses of the following options does your child usually drink each day?

	None	1	2	3	4 or more cups/glasses
Water	○	○	○	○	○
Cow's milk (or alternative)	○	○	○	○	○
Flavoured milk based drinks	○	○	○	○	○
Fruit juice	○	○	○	○	○
Fizzy drinks (including diet drinks)	○	○	○	○	○
Cordial or fruit drinks	○	○	○	○	○
Tea or coffee	○	○	○	○	○
Sports or energy drinks	○	○	○	○	○

Other (please specify)

Appendix E. Assumptions and decisions made from the 4DFR for each index component

DICE component	Assumptions and decisions made from 4DFR
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
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 colours of fruit • Serving size not considered
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
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 colours of vegetables • Serving size not considered
Bread and cereals: Servings of bread and cereals per day (e.g. bread, crackers, muesli, noodles, rice or pasta)	• 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: Proportion of whole meal/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 (e.g. breakfast cereals and milk) broken down into separate components

Meat and its alternatives: Serving of red meats, poultry, seafood, eggs, legumes, nuts and seeds per day	• Total number of servings for the 4 days calculated, average intake obtained - • Mixed dishes (e.g.) broken down into separate components • Processed meats such as ham and bacon included
Fluids: Frequency of consumption of beverages (e.g. water, cow's milk, flavoured milk, and fruit juice)	• Number of fluids for the 4 days calculated, average intake obtained • Smoothies included
Number of meals and snacks per day	• Number of meals and snacks for the 4 days calculated, average intake obtained
Frequency of prepared low fat foods, snack, and drink, especially saturated fat	• Percentage of saturated fat from total energy calculated by Foodworks
Frequency of prepared low salt foods, snack, and drink, especially low in salt	• Percentage of sugar from total energy calculated using sum of glucose, sucrose, and maltose
Frequency of prepared low sugar foods, snack, and drink, especially added sugar	• Sodium intake calculated by Foodworks