Determining the validity and reproducibility of the Healthy Heart Food Index

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Abstract

Background: Diet quality is associated with cardiovascular disease (CVD) risk, and the New Zealand (NZ) Heart Foundation has produced dietary guidelines aimed at reducing CVD risk for adult New Zealanders. At present, there is no valid and reproducible diet quality index for older adults living in NZ, which focuses on CVD risk.

Aim: To develop and determine the construct validity and reproducibility of the Healthy Heart Food Index (HHFI) for measuring dietary patterns in older adults living in New Zealand.

Method: The HHFI was developed based upon NZ Heart Foundation Guidelines. To assess HHFI reproducibility, 298 community dwelling participants aged 65-74 years completed the HHFI twice approximately four-weeks apart. To validate the index, 142 of these participants completed a four-day food record (4DFR). Construct validity was explored using Spearman's correlation coefficients and linear contrast analysis of selected nutrients from the 4DFR. Spearman's correlation coefficients, Wilcoxon ranked-signed tests, cross-classification, the weighted kappa statistic, and a Bland-Altman plot were used to assess HHFI reproducibility.

Results: Mean HHFI total scores were 69.3±10.8 and 68.9±11.1 from the first and second HHFI administrations respectively. These scores were positively correlated (r= 0.662; *P*<0.001) and cross-classification showed 55.4% of participants were categorised into the same tertile and 6.3% were grossly misclassified. The weighted kappa statistic was κ= 0.43, indicating moderate agreement between HHFI total scores. For construct validity, iron (r= 0.201), vitamin C (r= 0.174), and niacin (r= 0.205) (all *P*<0.05), and protein (r= 0.277), polyunsaturated fatty acids (r= 0.236), dietary fibre (r= 0.307), vitamin E (r= 0.205), folate (r= 0.268), potassium (r= 0.246), magnesium (r= 0.300), phosphorus (r= 0.281), zinc (r= 0.276), and selenium (r= 0.222) (all *P*<0.01), were positively correlated with the HHFI total score. Saturated

fat and cholesterol were negatively correlated (r= -0.097 and -0.035 respectively) with the HHFI total score, however this was a non-significant association (*P*>0.05). Linear contrast analysis showed a significant positive association between polyunsaturated fat, monounsaturated fat, dietary fibre, potassium, folate (*P*<0.05), vitamin E (*P*<0.01), and magnesium (*P*<0.005) and HHFI total scores.

Conclusion: Moderate adherence to the HHFI was shown in this population sample. Results indicate the HHFI demonstrated construct validity and good reproducibility for assessing CVD-related diet quality in older adults living in New Zealand. Further research is needed to examine the predictive validity of this index in relation to CVD risk.

Keywords: Diet quality index, validity, reproducibility, New Zealand, cardiovascular disease

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Chapter Three - Research Study Manuscript

Abbreviations

Name	Abbreviation
Alternative Healthy Eating Index	AHEI
Alternative Mediterranean Diet	AMED
Australian Recommended Food Score	ARFS
Automated Multiple-Pass Method	AMPM
Body Mass Index	BMI
Cardiovascular Disease	CVD
Cerebrovascular Disease	CVA
Coronary Heart Disease	CHD
Diet Quality Index	DQI
Diet Quality Index- International	DQI-I
Diet Quality Index Revised	DQI-R
Dietary Quality Score	DQS
Diet Quality Tool	DQT
Dietary Approaches to Stop Hypertension	DASH
Dietary Guideline Index	DGI
Dietary Index for a Child's Eating	DICE
Food-Based Dietary Guidelines	FBDGs
Food Frequency Questionnaire	FFQ
Food Pyramid Index	FPI
Four-Day Food Record	4DFR
Healthy Diet Indicator	HDI
Healthy Dietary Habits Index	HDHI
Healthy Dietary Habits Score for Adolescents	HDHS-A
Healthy Eating Index	HEI
Healthy Eating Index- 2005	HEI-2005
Healthy Eating Index- 2010	HEI-2010
Healthy Heart Food Index	HHFI
Healthy Heart Food Index- first administration	HHFI 1
Healthy Heart Food Index- second administration	HHFI 2
Low Density Lipoprotein-Cholesterol	LDL-C

Name	Abbreviation
Massey University Human Nutrition Research Centre	MUHNRC
Mediterranean Diet Score	MDS
Monounsaturated Fatty Acid	MUFA
New Zealand	NZ
New Zealand Diet Quality Index for Adolescents	NZDQI-A
New Zealand Women's Healthy Diet Index	NZW-HDI
Nutrient Reference Values	NRVs
Organisation for Economic Co-operation and Development	OECD
Polyunsaturated Fatty Acid	PUFA
Randomised Control Trial	RCT
Reduced Rank Regression	RRR
Researching Eating Activity and Cognitive Health	REACH
Saturated Fatty Acid	SFA
United States	US
World Health Organisation	WHO

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Chapter One - Introduction

Cardiovascular disease (CVD) is one of the lead causes of mortality in New Zealand (NZ) (Ministry of Health, 2018b) and globally, with the World Health Organisation (WHO) estimating 31% of deaths worldwide are attributed to CVD (World Health Organisation, 2017, Callow, 2006). In NZ, it is estimated that one in twenty adults are living with CVD (Ministry of Health, 2015a). There is a positive correlation between age and CVD risk (Lloyd-Jones *et al.*, 2006, Lerner and Kannel, 1986), with the 65 years and older population group presenting with a higher total CVD mortality, compared to 50-64 year olds residing in NZ (Ministry of Health, 2013a). As NZ has as an ageing population (Bryant *et al.*, 2004), with it being predicted that 20%-22% of New Zealanders will be over 65 years of age by 2032 (Stats NZ, 2017), this indicates a likely rise in CVD prevalence (Lloyd-Jones *et al.*, 2006, Lerner and Kannel, 1986).

Currently, reports show that the healthcare costs of individuals with CVD are significantly higher compared to those without CVD residing in NZ, suggesting that a further upsurge in CVD incidence will enlarge this economic burden further (Chan *et al.*, 2010). Research has demonstrated modifiable and non-modifiable contributors to CVD risk (Thayer *et al.*, 2010). While nothing can be done in relation to non-modifiable risk factors such as genetics/family history (The International Consortium for Blood Pressure Genome-Wide Association Studies, 2011), age, (Lloyd-Jones *et al.*, 2006), gender (Lerner and Kannel, 1986), and menopausal status (Rossouw *et al.*, 2007), changes to diet and lifestyle are modifiable factors that can significantly reduce CVD risk (Mozaffarian, 2016).

Risk factors such as smoking (Ambrose and Barua, 2004), alcohol consumption (Ronksley *et al.*, 2011), physical inactivity (Oguma and Shinoda-Tagawa, 2004), body weight (Hubert *et al.*, 1983), and dietary intake can be altered to reduce CVD risk (Mozaffarian, 2016). The longitudinal Framingham Heart Study has identified increased CVD risk to be positively associated with individuals categorised as overweight (Body Mass Index (BMI) ≥25.0kg/m^2- 29.9kg/m^2) and obese (BMI ≥30.0kg/m^2) (Wilson *et al.*, 2002). In NZ, one-third of the adult population are

considered obese (30.9%) (Ministry of Health, 2019b). One of the key contributors for this obesity epidemic is the dietary intake of the NZ adult population. The 2008/09 New Zealand Adult Nutrition Survey found median reported energy intake exceeded energy expenditure, suggesting an energy intake imbalance. This is supported by the high consumption of energy rich, nutrient poor foods such as, sugar-sweetened beverages, takeaways, ice-cream, and chocolate (University of Otago and Ministry of Health, 2011). In contrast, dietary patterns that have been shown to be protective against obesity and cardioprotective are nutrient rich, high in fruits, vegetables, whole grains, and legumes (Mozaffarian, 2016). In the past, links have been established between specific nutrient intake and CVD risk, such as saturated fat intake increasing CVD biomarkers (Katcher *et al.*, 2009).

Diet quality has multiple definitions, but essentially the term refers to the degree an individuals' dietary intake adheres to specific dietary recommendations or the extent one's dietary habits assist with disease prevention (Kant, 1996). Research has identified the greater the diet quality the lower CVD risk (Toft *et al.*, 2007, O'Reilly and McCann, 2012). For instance, women and men who had the highest adherence to the Dietary Guidelines for Americans measured using the Healthy Eating Index (HEI), had a 28% and 39% reduced CVD risk compared to those with the poorest adherence (McCullough *et al.*, 2002). Another study in the United States found better diet quality expressed through four separate dietary assessment tools to be positively associated with reduced CVD mortality (Reedy *et al.*, 2014).

Traditional methods to analyse dietary intake focus on assessing the health impact of single nutrients. However, there has been a shift from this single nutrient emphasis to considering the whole diet or dietary patterns (Hu, 2002, Tucker, 2010). This includes examining the impact concurrent exposure to foods, food groups, and a variety of nutrients has on diet quality and hence, health and disease risk (Tucker, 2010). The application of this method is presented from the Dietary Approaches to Stop Hypertension (DASH) study, which revealed that low fat and meat consumption along with a high fruit, vegetable, and wholegrain intake reduced blood pressure. Dietary patterns as identified in the DASH study reflect more accurately how people

eat (that is, a variety of nutrients which all interact to alter their impact on health and disease risk) (Sacks *et al.*, 2001).

Diet quality indices (DQIs) are one way of effectively comprehending dietary patterns. Essentially a DQI is formulated based upon a set of predefined criteria or guidelines, and the closer each respondent adheres to a specific food and nutrition guideline the greater their score (Waijers *et al.*, 2007, Wong *et al.*, 2013). For instance, a DQI has been developed to measure how closely people adhere to Mediterranean diet guidelines (Trichopoulou *et al.*, 1995). The Diet Quality Index and the HEI are the most popular DQIs, which are founded upon set dietary guidelines (Patterson *et al.*, 1994, Kennedy *et al.*, 1995). However, these dietary indices have been developed based on the United States dietary guidelines (Kennedy *et al.*, 1995, Patterson *et al.*, 1994), making it harder and less applicable to a NZ population with some differences in recommended dietary guidelines (Wong *et al.*, 2013). Currently, the New Zealand Diet Quality Index for Adolescents (Wong *et al.*, 2013), the Healthy Dietary Habits Index (Wong *et al.*, 2017), Healthy Dietary Habits Score for Adolescents (Wong *et al.*, 2014), and the NZ Women's Healthy Diet Index (Fenner, 2015) are the only validated indices available that are formulated for the NZ adolescent and adult population, based upon NZ-specific dietary guidelines (Wong *et al.*, 2013). Another NZ-based dietary index is the recently validated Dietary Index for a Child's Eating formulated for children aged 2-8 years residing in NZ (Delshad *et al.*, 2018). Diet quality indices can be extremely valuable in public health sectors, as they acknowledge the whole diet and the degree of set dietary guideline adherence (Kant, 1996, Wong *et al.*, 2013, Reedy *et al.*, 2014). This makes it easier to communicate understandable dietary advice to the public (Reedy *et al.*, 2014).

The National Heart Foundation has created the NZ Heart Foundation Guidelines that include specific dietary recommendations to help maintain and achieve optimal heart health for New Zealanders. These guidelines were updated in 2018 and are based upon 'Nine steps for healthy heart eating' which include having plenty of fruit and vegetables, choosing wholegrain foods and low-fat dairy options, consuming healthy oils (e.g. sunflower and canola oil), nuts and seeds, and restricting processed

meat, sugar-sweetened beverages, junk foods (e.g. sweet and savoury snack foods), and takeaways. A DQI based upon adherence to the NZ Heart Foundation Guidelines would allow for greater specificity of dietary intake towards CVD risk for New Zealanders (Heart Foundation of New Zealand, 2018).

When developing a dietary assessment tool it is important to assess both its validity and reproducibility (Newby *et al.*, 2003, Cade *et al.*, 2002). Validity measures the extent to which a tool (DQI) is measuring what it is designed to measure, or how closely the tool aligns with the compared 'gold standard' method of diet measurement (Kimberlin and Winterstein, 2008). There are three DQI validation techniques that can be executed to validate a DQI: construct validity, content validity, and relative validity (Kaplan *et al.*, 1976). Construct validity refers to the alignment between the assessed tool and its referenced theoretical elements. Content validity examines if the tool contains all of the elements it is assumed to measure (Kaplan *et al.*, 1976). Lastly, relative (or criterion) validity assesses the tool in comparison to the gold standard (Streiner *et al.*, 2014). The other method of examining the effectiveness of a DQI is reproducibility (or reliability) (Newby *et al.*, 2003, Cade *et al.*, 2002). Reproducibility refers to the ability of a dietary assessment tool to produce the same findings on the same population group but at two different points of time (Cade *et al.*, 2002). Assessing the reproducibility of a DQI is important as it indicates whether a dietary assessment tool can produce reliable findings consistently when repeatedly administered (Cade *et al.*, 2002, Newby *et al.*, 2003).

Based upon the information discussed, there is a clear need for a validated and reliable CVD-focussed DQI for 65-74 years olds residing in NZ. By developing and validating this DQI it will provide opportunities for greater understanding on dietary patterns associated with CVD, which will help to put forth easier dietary advice for this population group in NZ.

Aims and Objectives

The aim of this study is to develop and assess the construct validity and reproducibility of the Healthy Heart Food Index (HHFI), which is focused on evaluating diet related CVD risk in adults aged between 65-74 years old living in NZ.

The objectives for this study are:

1. To develop the scoring and cut-off criteria for the HHFI based on NZ Heart Foundation Dietary Guidelines.
2. To assess the construct validity of the HHFI using the nutrient intakes from four-day food records.
3. To examine the reproducibility of the HHFI by repeating this dietary assessment tool on the same population group one-month apart.

Thesis Structure

This thesis is separated into four chapters. The first chapter introduces the topic, scope, and justification of this study. Chapter two explores past literature related to this study including, an overview of CVD, dietary assessment methods and their limitations, food, nutrient, and dietary pattern analysis, an overview of the purpose, application, and development of DQIs, a summary of available DQIs, the NZ Heart Foundation Guidelines, and dietary assessment tool validation and reproducibility techniques. Chapter three present a research study manuscript, which provides the complete research conducted for this thesis broken down into an abstract (also on page 2), introduction, methods, results, discussion, and conclusion sections. Lastly, chapter four provides the overall conclusion and recommendations from this study.

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Researcher's Contributions to Thesis

Table 1. Researcher's contributions to thesis

Author	Contribution to Thesis
Harriet Guy	REACH study data collection, data entry (4DFRs), HHFI scoring and cut-off criteria development, statistical analysis, results interpretation, and discussion. Author of thesis.
Dr Kathryn Beck	Primary academic supervisor, primary investigator of REACH and thesis study design, application for funding and ethics, development of HHFI. HHFI scoring and cut-off criteria development, participant recruitment, and data collection assistance. Supervision of statistical analysis and interpretation of results and discussion. Thesis revision and approval.
Dr Cheryl Gammon	Secondary academic supervisor, assistance with data entry and REACH study overview, academic supervision, and thesis chapter feedback.
Cassie Slade	REACH research assistant, participant recruitment, participant screening, data collection, and data entry (4DFRs).
Owen Mugridge	Participant recruitment and data collection.
Angela Yu	Data collection and 4DFR data entry
Dr Pamela Von Hurst, Dr Cathryn Conlon	Co-investigators on REACH, assistance with REACH study data collection.
Karen Mumme	Data collection and data entry (4DFRs and HHFI)
Anne Hiol, Jamie de Seymour, Nicola Gillies	Data collection and 4DFR data entry
Cherise Pendergrast	4DFR data entry assistance

HHFI, Healthy Heart Food Index; REACH, Researching Eating Activity and Cognitive Health; 4DFR, Four-Day Food Record

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Chapter Two - Literature Review

Cardiovascular disease

Cardiovascular disease (CVD) is a collective term used to cover multiple health conditions involving the heart and blood vessels. These conditions include hypertension, heart failure, cerebrovascular disease (CVA or stroke), coronary heart disease (CHD), congenital heart disease, peripheral vascular disease, rheumatic heart disease, and cardiomyopathies (Callow, 2006, World Health Organisation, 2017).

Cardiovascular disease - globally and in New Zealand

The World Health Organisation (WHO) has estimated that 17.9 million people died from a CVD event in 2016, with the majority (85%) of these deaths from CHD and stroke (World Health Organisation, 2017). It is predicted that the CVD mortality rate will rise to nearly 23.6 million by 2030 (World Health Organisation, 2019). In New Zealand (NZ), CVD is one of the leading causes of death and responsible for about 33% of deaths annually (Ministry of Health, 2018b). In fact for women CVD is the leading cause of death, responsible for twice as many deaths compared to any other single cause (Ministry of Health, 2019a). It also disproportionately affects some ethnic groups more than others, with the CHD mortality rate among adults of Māori ethnicity twice as high compared to non-Māori adults (Ministry of Health, 2018a).

Non-modifiable risk factors

There are a number of non-modifiable risk factors that impact on CVD prevalence including age (Lakatta, 2002), genetics/family history (Kathiresan and Srivastava, 2012), ethnicity (Chan *et al.*, 2008, Cooper, 2001), gender (Lerner and Kannel, 1986), and menopausal status (Mendelsohn and Karas, 1999). In NZ the population is ageing, with the older adult (65 years and over) population group increasing by 22.5% since 2006 (Stats NZ, 2015). Cardiovascular risk and prevalence is positively

associated with ageing due to the cardiovascular structural remodelling (e.g. increase in vascular stiffening and ventricular wall thickness) and functional changes (e.g. vascular tone changes) that occur (Lakatta, 2002). Therefore taking this knowledge on board, CVD prevalence rates are likely to increase as the ageing population continues to grow in NZ.

Research has found that for the majority of CVD disorders, specific inherited DNA sequence variants impact risk (Kathiresan and Srivastava, 2012). For example, premature atherosclerotic CVD presenting in a parent increases CVD risk in their children (Lloyd-Jones *et al.*, 2004). Additionally, another study identified specific genes associated with blood pressure regulation in 200,000 participants of European descent. Variants of these known genes were linked to CHD, hypertension, and stroke (The International Consortium for Blood Pressure Genome-Wide Association Studies, 2011). However, the degree of influence genetics has on CVD risk depends on the presence of other risk factors (e.g. age and gender) (Kathiresan and Srivastava, 2012).

Ethnicity has been shown to be independently associated with CVD prevalence. An NZ-based study identified that compared to non-Māori and non-Pacific peoples; Māori had the highest rate of CVD (Chan *et al.*, 2008). Apart from genetics (Wang *et al.*, 2005, Wang *et al.*, 2012, Goodarzi *et al.*, 2005), modifiable factors such as social inequality (Cooper, 2001) and socioeconomic status (Winkleby *et al.*, 1999) are also shown to be associated with CVD development.

There are differences in CVD rates by gender, with women tending to have a longer life span than men and developing CVD approximately 10-15 years later (Rossouw, 2002, Regitz-Zagrosek *et al.*, 2006). The increase in CVD risk and prevalence in older women is thought to be due to the reduction in endogenous oestrogen post-menopause, as oestrogen is considered to have cardioprotective properties (Mendelsohn and Karas, 1999). This gender hypothesis is supported by findings from The Framingham study, which identified that CVD incidence rates were significantly

lower for pre-menopausal women compared with post-menopausal women (Kannel *et al.*, 1976).

Modifiable risk factors

There are multiple known modifiable risk factors of CVD, including smoking (Ambrose and Barua, 2004), alcohol consumption (Ronksley *et al.*, 2011), physical activity (Kohl, 2001), body weight (Lavie *et al.*, 2009), and dietary intake (Mozaffarian, 2016). These modifiable factors can exacerbate or reduce CVD risk or other known CVD risk factors (Ignarro *et al.*, 2007). The NZ CVD Risk Chart is one tool used to roughly establish CVD risk among the NZ population. This tool uses factors including, age, gender, blood pressure, family history, obesity, smoking, and cholesterol levels to determine CVD risk, which can appear as mild (<2.5% CVD risk occurrence) to very high (>30% CVD risk occurrence) (New Zealand Guidelines Group, 2009).

The impact alcohol consumption has on CVD risk has been debated. Some observational studies have found alcohol intake to have cardioprotective effects (Ronksley *et al.*, 2011). A meta-analysis of 26 quantitative studies found light to moderate wine consumption had an inverse association with CVD-related risk (Di Castelnuovo *et al.*, 2002). Whereas, another meta-analysis reported heavy alcohol intake to be positively associated with relative stroke risk, and light or moderate consumption to be negatively associated with total and ischemic stroke risk (Reynolds *et al.*, 2003). The general consensus is moderate alcohol consumption (approximately one to two drinks daily) does not increase CVD mortality risk (American Heart Association, 2019) or long-term health outcomes (Heart Foundation of New Zealand, 2019b).

There is inarguable evidence that regular moderate physical exercise contributes to CVD prevention (Ignarro *et al.*, 2007, Kohl, 2001). For example, a meta-analysis showed a dose-response relationship between physical activity and CVD risk reduction in women, and found a slight increase in physical activity by inactive women would reduce their CVD risk (Oguma and Shinoda-Tagawa, 2004). This

finding is supported by a meta-analysis showing physical inactivity to increase the risk of CVD (Kohl, 2001).

Being classified as obese (Body Mass Index (BMI) ≥30.0kg/m^2) or overweight (BMI 25.0-29.9 kg/m^2) has also been shown to elevate CVD risk (Lavie *et al.*, 2009). Obesity alters the cardiovascular structure and function, specifically by increasing the total blood volume and cardiac output due to excessive adipose tissue causing a greater cardiac workload (Alpert, 2001, Lavie *et al.*, 2009). Further it impacts other risk factors such as diabetes, hypertension, and dyslipidaemia (Lavie *et al.*, 2009). Currently, NZ has the third highest rate of adult obesity in the Organisation for Economic Co-operation and Development (OECD) (Ministry of Health, 2019c). This is supported by national data finding one in three adults (30.9%) were classified as obese (Ministry of Health, 2019b).

Cardiovascular disease and diet

Over the years various studies have examined the relationship between diet and CVD (Katcher *et al.*, 2009, Mozaffarian, 2016). It is well established that a heart-healthy diet assists in CVD prevention and reduces CVD mortality. A heart-healthy dietary pattern includes a dietary intake high in fruits and vegetables, and a moderate intake of whole grains, legumes, lean meats (poultry, fish, and seafood), reduced-fat dairy, and unsaturated fatty acid sources (nuts, seeds, and certain healthy oils). This diet also has a low/restricted intake of saturated fatty acid (SFA), sodium, refined carbohydrates, and added-sugars (Freeman *et al.*, 2017).

Dietary intake of fruits and vegetables has the most substantial evidence in regard to reducing CVD risk (World Health Organisation, 2003). It is likely that multiple biological processes are behind how fruits and vegetables reduce CVD risk, yet many of the mechanisms still remain unclear. The low glycaemic load and energy density from fruits and vegetables may contribute, although the plethora of nutrients and phytochemicals (e.g. fibre, folate, and potassium) found in fruits and vegetables

either working alone or jointly are likely to be more important contributors (Bazzano *et al.*, 2003).

Whole grain intake has also been shown to assist in CVD prevention (Jacobs and Gallaher, 2004). Whole grains include brown rice, dark bread, whole-grain breakfast cereals, and popcorn. Whole grains contain the endosperm, germ and bran, compared to refined grains, which are stripped of the germ and bran during the milling process (Mozaffarian *et al.*, 2013). Subsequently, whole grains contain more fibre, magnesium, and other functional compounds compared to refined grain products (Liu, 2007). Dietary fibre is defined as a non-digestible carbohydrate (Katcher *et al.*, 2009), and has been found to lower serum lipids, by reducing cholesterol (specifically low density lipoprotein-cholesterol (LDL-C)) and bile acid absorption (Marlett *et al.*, 1994, Lia *et al.*, 1995).

A meta-analysis examining prospective cohort studies and randomised control trials (RCTs) exploring the relationship between whole grains and CVD shows 48-80g (3-5 servings) of whole grains daily to be associated with a 21% reduced risk of CVD, compared to 'rare or never eaters' of whole grains (Ye *et al.*, 2012). Additionally, the results from another meta-analysis found a consistent inverse correlation between dietary whole grain intake and CVD incidence from identified cohort studies (Mellen *et al.*, 2008). Conversely, refined carbohydrates (sweets or highly processed sugar-based foods) and high glycaemic response foods (white bread) are associated with increased CHD risk (Liu *et al.*, 2000, Hu and Willett, 2002, Hu, 2010).

Research has shown a diet dominant in plant-based protein compared to animal protein sources is inversely associated with CVD mortality rates, while a high intake of animal protein (e.g. red meat and eggs) is associated with elevated CVD mortality (Song *et al.*, 2016). Furthermore, relative replacement of animal protein sources (red meat, poultry, eggs) with plant-based protein sources (legumes, beans, nuts) is recommended for CVD prevention. This research backs the healthy-heart dietary pattern, which supports moderate consumption of lean animal protein sources and plant-based protein alternatives (Freeman *et al.*, 2017).

Research has found the type of dietary fat consumed to be associated with reducing known biomarkers of CVD risk. Evidence suggests that replacement of excessive SFAs with polyunsaturated fatty acids (PUFAs) assists with CVD prevention (Mozaffarian *et al.*, 2010). Unsaturated fatty acid food sources include a variety of nuts, seeds, and healthy oils (e.g. canola, sunflower, olive oil) (Freeman *et al.*, 2017). Saturated fatty acid food sources include selected meats (red meat, poultry, processed meats), dairy products (Valsta *et al.*, 2005), and some oils (e.g. palm and coconut oil) (Freeman *et al.*, 2017). Research has shown that SFA intake has a dose-response relationship towards elevating LDL-C levels, which is associated with increasing CVD risk (Katcher *et al.*, 2009, Mozaffarian, 2016). A study using the data from the Nurses' Health Study and Health Professionals Follow-up Study noted the CVD mortality rate of these population groups was inversely associated with unsaturated fatty acid consumption, but positively correlated to higher saturated and trans fat intake (Wang *et al.*, 2016). Additionally, nut consumption has been shown to have an inverse association with overall CVD risk (Luo *et al.*, 2014, Freeman *et al.*, 2017), with pooled RCTs indicating nut intake to have a cholesterol lowering effect in a dose-related manner (Sabaté *et al.*, 2010).

A high salt intake has been shown to significantly increase the risk of CVD. It has been demonstrated that reducing salt intake will lower blood pressure and hence, the risk of CVD (He *et al.*, 2013, Bibbins-Domingo *et al.*, 2010). One meta-analysis showed a reduction in salt intake for four weeks or more to significantly lower blood pressure in both hypertensive and normotensive participants, thereby reducing CVD risk (He *et al.*, 2013).

Dietary assessment

The assessment of dietary intake can be conducted at three levels, food supply, household, or individual. Food supply data (or food balance sheets) present gross estimates of the quantity of national food availability for a country's population. Dietary assessment at the household level is often collected from household budget

surveys (Biró *et al.*, 2002). Dietary assessment at an individual level can help establish links between dietary intake, health, and disease (Willet, 1998, Biró *et al.*, 2002).

At an individual level there are multiple dietary assessment methods employed to assess this link between diet and health outcomes (Biró *et al.*, 2002, Shim *et al.*, 2014). The four most utilised methods are presented in Table 1. These methods can be categorized into retrospective and prospective methods (Magkos and Yannakoulia, 2003). The former includes food frequency questionnaires (FFQs), diet recalls, and diet histories (Thompson and Byers, 1994, Magkos and Yannakoulia, 2003). Food frequency questionnaires and diet histories are both long-term dietary assessment tools that collect dietary consumption over weeks, months, or years (Biró *et al.*, 2002). While prospective methods (food records) (Thompson and Byers, 1994) and diet recalls are classified as short-term methods, as they collect food and drink consumption over a day or multiple days (Biró *et al.*, 2002). Both of these short-term methods can provide an accurate and detailed measure of nutrient intake (Shim *et al.*, 2014)

It is important to choose a dietary assessment tool that meets the objectives of the study undertaken. Key factors to take into consideration include the accuracy of intake estimations required (absolute or relative), population demographics (e.g. age, education), the strengths and weaknesses of each method (see Table 1), and resources available (e.g. equipment, money, and skilled interviewers) (Biró *et al.*, 2002, Shim *et al.*, 2014).

Table 1. Summary of common individual level dietary assessment methods

Assessment method	Course of action	Collected data	Strengths	Limitations
Food record	Participant records their dietary consumption in real-time over 3 - 7 days, including food and drink item quantities. - Food records are either weighed (e.g. using scales) or estimated (e.g. using household measures, food models, photographs). - Weekends should be included in appointed recording days.	Actual intake from a set time period. - Short-term - Prospective - Open-ended survey - Quantitative	- High accuracy - weighing considered 'gold standard' for quantifying food and nutrient intake. - No reliance on participant memory. - A person other than the participant can record their intake (e.g. for children). - Omission of intake may be minimal. - Visual aids can be used to help participant accurately record intake quantities.	- Reliance on participant cooperation and motivation. - Participant literacy required (unless recording is done by another person). - Real-time recording may alter usual intake. - Participant fatigue, especially at the end of recording period may alter intake recorded, and hence, reduce reliability of findings. - Lack of participant real-time recording could lead to omitting or altering actual intake. - Greater amount of incomplete food records and lower validity the longer the reported food intake period (e.g. day 1-3 reported intake more complete and valid compared to day 6-7).
24-hour recall	A 15 - 30 minute interview in which a trained interviewer asks a participant to recall all food and drink intake over the preceding day or 24 hours. Multiple 24-hour recalls may be undertaken to assess usual dietary intake. - Trained interviewers are required who are proficient in food and meal identification and typical dietary habits within respondent demographics.	Actual intake over continuous 24-hour period. - Short-term - Retrospective - Open-ended survey - Quantitative	- Direct engagement with participant increases reliability of data. - Applicable to wide range of demographics. - No literacy requirements. - Low participant burden. - Relatively short administration/interview time. - Ability for standardized data collection, to help minimize time and expense. - Method does not affect participants' dietary intake.	- Reliant on participant memory. - Dependent on participant perception of portion size, which could be inaccurate. - Trained interviewers are needed. - Recall is only a snapshot of dietary intake, and is hence not reflective of usual intake. - Single day dietary intake is not sufficient to establish habitual dietary intake.

Assessment method	Course of action	Collected data	Strengths	Limitations
Food frequency questionnaire	Self or interviewer administered 20 - 30 minute questionnaire regarding frequency of food and drink consumed over past weeks, month, to a year. - Questionnaire typically covers 100 - 150 foods items. - Different questionnaires can be developed to focus on several or specific nutrients, food items, food groups, and dietary patterns.	Estimated usual intake over predefined time period. e.g. past month to year. - Long-term - Retrospective - Close-ended survey - Qualitative or semi-quantitative	- Ability to rank participants according to intake of nutrients, food items, and food groups - Can be self-administered. - Relatively inexpensive administration. - Questionnaires are often pre-coded, so minimal data entry required. - Minimal participant burden.	- Reliance on memory for past eating behaviours. - Current intake may alter recall of actual past dietary intake. - Quantification inaccuracy due to poor memory recall or estimation of portion sizes. - Needs to be developed and validated for the population of its intended use.
Diet history	This assessment method has multiple meanings. Generally this term refers to the use of dietary assessment methods to ascertain dietary intake including food characteristics, frequency, and quantity details. - Some diet histories include a three-step completion of a 24-hour recall, three-day food diary and a food frequency questionnaire.	Estimated usual intake over predefined time period. e.g. past month to year. - Long-term - Retrospective - Open-ended survey - Qualitative or quantitative	- Combined methodology - allowing weaknesses of methods to be overcome. - Does not influence participants' dietary intake. - Provides details of how food consumed is prepared and cooked, which can provide greater accuracy of nutrient intake.	- Skilled staff needed. - Three-day food diary is often not included in data collection. - High labour and time demand. - Significant participant burden.

Table derived from Biró *et al*. (2002), Thompson & Byers (1994), and Shim *et al.* (2014).

No dietary assessment method is perfect (Biró *et al.*, 2002, Shim *et al.*, 2014). All dietary assessment methods have a risk of containing both systematic and random errors (Bingham, 1987, Biró *et al.*, 2002). These errors can result from inappropriate food composition table use (Ireland *et al.*, 2002), incorrect food coding (Verger *et al.*, 2002), inaccurate portion size approximation, response and sampling bias (Bingham, 1987). Overall, a range of errors can occur at many stages of the dietary assessment process. Other errors include daily diet variation and data entry human error occurrence (Bingham, 1987, Shim *et al.*, 2014).

A frequent limitation in the collection of dietary data is under-reporting (Macdiarmid and Blundell, 1998, Gemming *et al.*, 2013). A number of factors effect under-reporting with increased levels of under-reporting observed in individuals who are overweight and obese (Gemming *et al.*, 2013, Macdiarmid and Blundell, 1998). Other factors that affect self-reporting of dietary intake include variations in lifestyle and physical activity levels (O'Loughlin *et al*., 2013).

Inaccurate reporting is a common issue for many dietary methods as often participants rely on memory for diet recall or habitual dietary intake (Biró *et al.*, 2002). For example, a limitation of FFQs is that a participant's perception of their current dietary intake can influence how they remember or perceive their past dietary intake, leading to inaccurate FFQ responses (Biró *et al.*, 2002, Shim *et al.*, 2014). Social desirability can alter reported dietary intake, with participants changing their reported intake to better align with a particular dietary change being promoted or towards what participants perceive as 'good' or 'bad' foods (Thompson and Byers, 1994).

Epidemiological studies assessing the link between diet, health, and disease have often used specific biomarkers to measure dietary intake of nutrients and food groups. These studies have found this method to be successful, showing biomarkers to be significantly associated with dietary intake (Kim *et al.*, 2012, Lim *et al.*, 2012, Katcher *et al.*, 2009). This method avoids typical errors present in common dietary assessment methods including social desirability bias, memory recall inaccuracy, and participant reliance to accurately describe their intake (Potischman, 2003).

However, limitations of this alternative method include not taking into account individual differences in metabolism and absorption of foods (Kuhnle, 2012), or homeostasis regulation (Kaaks *et al.*, 2002), and the majority of biomarkers are explicit to particular nutrients and hence, not reflective of the scope of dietary consumption (Thompson *et al.*, 2010). Biomarkers cannot provide dietary recommendations to assist an individual to alter their dietary intake accordingly, unlike common dietary assessment methods (Shim *et al.*, 2014). Additional limitations to note are the invasiveness and expense of this method (Hedrick *et al.*, 2012, Thompson *et al.*, 2010).

Technological advancements are currently being developed to reduce the limitations of dietary method assessments discussed previously (Shriver *et al.*, 2010, Illner *et al.*, 2012). These dietary assessment technologies typically aim to reduce participant burden, improve the feasibility, cost, and effectiveness of the dietary assessment method utilised, allow for multiple self-administrations, and increase data collection accuracy (Shim *et al.*, 2014).

Developing technologies include interactive computer-based tools to improve data handling and analysis processes (Shim *et al.*, 2014). For example, the Automated Multiple-Pass Method (AMPM) has been developed for 24-hour recall administration. The AMPM allows investigators to standardize the assessment of dietary intake data, improving accuracy of the data and findings (Moshfegh *et al.*, 2008). However, weaknesses of these technological innovations include the lack of familiarity participants may have with these new technologies (Hercberg, 2012), the transfer, storage, and battery life of some new technical tools (Sun *et al.*, 2010), and unfortunately many of these new technologies do not overcome concerns related to self-reporting (Shim *et al.*, 2014, Illner *et al.*, 2012).

The traditional approach - link between nutrients and disease

Once dietary intake has been collected it needs to be analysed. Previous diet-related epidemiologic studies have often undertaken a traditional approach, by focusing on the relationship between single nutrients or foods and disease (Newby *et al.*, 2003,

Hu, 2002, Willet, 1998). This traditional approach has been beneficial in understanding the quantities (e.g. inadequate or excessive) of particular foods or nutrients people should be consuming to help achieve optimal health and reduce disease risk (Willet, 1998).

Typically, food and nutrient analysis involves the transformation of dietary intake data into energy and nutrient (e.g. protein, vitamin C, sodium) intake (Jacobs, 2012). This transformation occurs using values found on nutrient databases and food composition tables. It is important that food composition databases are checked regarding food item variety and accessibility prior to use, as this will affect nutrient and food intake information produced. It is also essential to consider the accuracy of values and population relevancy when using food composition data (Mann and Truswell, 2017).

Once food and nutrient analysis is completed, the energy and nutrient values are compared to specific reference standards (Mann and Truswell, 2017) such as Nutrient Reference Values (NRVs) and Food-Based Dietary Guidelines (FBDGs). Nutrient reference values are a collection of nutrient recommendations based on scientific knowledge for NZ and Australian populations (National Health and Medical Research Council, 2006). The NRVs contain recommendations categorised by gender and life stage. For example, the recommended dietary intake of calcium for males and females over 71 years of age is 1,300mg per day (National Health and Medical Research Council, 2017).

The aim of FBDGs is to provide country-specific understandable dietary advice based upon translated nutrient recommendations. The formulation of FBDGs incorporates many factors such as, diet and health associations, country specific diet-related health concerns, culture, food consumption patterns, and food accessibility (Mann and Truswell, 2017).

For instance, in developed countries the main health focus is on obesity and chronic disease prevention, while in developing countries the primary health concern is malnutrition (Wardlaw, 2013, Ministry of Health, 2015c). New Zealand population

based FBDGs include the Current Food and Nutrition Guidelines (Ministry of Health, 2015b). There are various versions of the Current Food and Nutrition Guidelines, each providing age-specific recommendations for healthy dietary intake and physical activity for New Zealanders (Ministry of Health, 2015c) (e.g. Eating and Activity Guidelines for New Zealand Adults (19-64 years old) (Ministry of Health, 2015c) and Food and Nutrition Guidelines for Healthy Older People (65 years and over)) (Ministry of Health, 2013b). In addition, non-governmental health organisations such as the New Zealand Heart Foundation have established their own dietary guidelines (Heart Foundation of New Zealand, 2018).

Food and nutrient analysis limitations

Although the traditional approach focussing on individual foods and nutrients to understand the links between dietary intake, health, and disease have been invaluable, there are multiple limitations in this approach (Hu, 2002). Firstly, this approach does not take into consideration that people do not consume single nutrients in isolation, but consume a variety of nutrients that interact in foods (Hu, 2002, National Research Council (US) Committee on Diet and Health, 1989). For example, in a meal non-haem iron absorption increases if vitamin C is present (Hu, 2002).

Secondly, this approach does not take into consideration that some nutrients are highly inter-correlated in foods (e.g. calcium and phosphorus in milk), making it difficult to accurately separate the effects each nutrient has (Lee *et al.*, 1988). Thirdly, investigations on several nutrients may present inaccurate significant findings that are only by chance (Farchi *et al.*, 1989). Also, single nutrient analysis may be influenced by dietary patterns, as dietary patterns are often linked to nutrient intake (Randall *et al.*, 1990, Hu, 2002). For instance, the relationship between dietary fat intake (nutrient) and CHD risk can be confounded by dietary patterns. This is because a dietary pattern high in fruits, vegetables, whole grains, fibre, and folate has been associated with low dietary fat intake (single nutrient) (Ursin *et al.*, 1993). Finally, the effect of a single nutrient may be too small to be recognised, but by using dietary methods that acknowledge the accumulative effect of multiple nutrients and

foods, clear associations could be significant and recognised (Hu, 2002, Sacks *et al.*, 1995). From the information presented above there are clear limitations when a traditional approach is undertaken to understand the relationship between diet, health, and disease (Hu, 2002).

An alternative approach - dietary pattern analysis

A complementary and alternative approach to assessing associations between dietary intake, heath, and disease involves dietary pattern analysis (Hu, 2002, Kennedy *et al.*, 1995, Patterson *et al.*, 1994). The term 'dietary patterns' refers to food and nutrient intake combinations identified over a period of time through eating behaviours. Unlike a traditional approach, dietary pattern analysis does not look at single nutrients in isolation, but considers the effects of the whole diet on health and disease risk. Compared to a traditionalist approach, dietary pattern analysis fits better with real world dietary intake, as it acknowledges that foods and nutrients are consumed in combination (Hu, 2002). There has been a shift towards using a dietary pattern approach in nutrition research (Moeller *et al.*, 2007, Tucker, 2010). Subsequently, a benefit of a dietary pattern approach is it may provide more realistic understandable dietary guidance towards managing dietary disease treatment and prevention (Hu, 2002). Additionally, it may also lead to dietary advice that is easier for the public to understand and implement into their diets (National Research Council (US) Committee on Diet and Health, 1989, Reedy *et al.*, 2014). Dietary patterns can be derived empirically or through the use of dietary indices (Tucker and Newby, 2004, Hu, 2002).

Empirically derived dietary patterns

Empirically derived dietary pattern analysis can be conducted through the multivariate techniques such as factor or cluster analysis (Tucker and Newby, 2004, Hu, 2002), and reduced rank regression analysis (RRR) (Tucker, 2010). Factor analysis works by using dietary intake data typically collected from FFQs (Randall *et al.*, 1990, Hu *et al.*, 2000, Hu *et al.*, 1999). This method identifies the underlying common food consumption elements (dietary patterns). For example, 'meat and vegetable' and

'milk and yoghurt' dietary patterns were identified through factor analysis of an iron FFQ aimed at identifying risk factors for iron deficiency (Beck, 2013). Eventually, a summary score is produced for each participant for each common dietary pattern, which can then be compared to health and disease topics of interest via regression or correlation analysis (Randall *et al.*, 1990).

On the other hand, cluster analysis organises people with similar diets together into subgroups (Hu, 2002). The arrangement of clusters is based upon factors including, frequency of food consumption (Millen *et al.*, 2001), average quantity of food intake (Akin *et al.*, 1986), and the contribution of each food or food group to total energy intake (WirfÄLt and Jeffery, 1997).

While factor and cluster analysis do not depend on past nutrition knowledge reasoning, RRR analysis uses a combination of past nutritional knowledge and empirical analysis. This newer method assesses relevant intermediate biomarkers to create factors that best predict specific profiles (metabolic or biochemical) (Tucker, 2010).

Theoretically derived dietary patterns

Diet quality indices - alternative dietary assessment method

Another method of dietary pattern analysis is diet quality indices (DQIs) (Alkerwi, 2014). This theoretically derived dietary pattern analysis undertakes an a priori approach, by using past nutritional knowledge from selected dietary recommendations (Waijers *et al.*, 2007, Hu, 2002). Diet quality indices are often classified upon the composition of the following nutritional components: foods, food groups, and/or nutrient intake, which are known to impact health (Waijers *et al.*, 2007, McNaughton *et al.*, 2008). These nutritional components are classified to be either healthy or unhealthy, and then quantified and totalled to produce an overall measure of diet quality in the form of a summary (total) score. This score indicates how closely an individual's diet adheres to specific dietary recommendations, and hence, the extent of diet quality (Hu, 2002, Newby *et al.*, 2003).

Diet quality is difficult to measure, and there is poor definition surrounding this commonly used term (Alkerwi, 2014). Generally, diet quality is used to explain how closely a person's dietary intake aligns with dietary recommendations, or assists with specific disease prevention (Kant, 1996). Despite the lack of a definitive classification (Alkerwi, 2014), diet quality has become an increasingly used term in nutrition epidemiology to examine dietary habits, and to investigate the effectiveness of dietary interventions in selected populations (Patterson *et al.*, 1994, Alkerwi, 2014). Various DQIs have been created or adopted to evaluate aspects of diet quality (Fransen and Ocké, 2008, Waijers *et al.*, 2007).

Purpose and application of diet quality indices

The purpose of any DQI must be established prior to formation and application (Thompson and Subar, 2017). Diet quality indices range from simple tools with the purpose of assessing adherence to specific dietary guidelines, to complex indices, which require specific desired nutrient intakes (Waijers *et al.*, 2007, Arvaniti and Panagiotakos, 2008). Many studies have developed DQIs to examine adherence to specific dietary guidelines (Kennedy *et al.*, 1995, Patterson *et al.*, 1994, McCullough *et al.*, 2002, McNaughton *et al.*, 2008). For example, the United States (US) Department of Agriculture Healthy Eating Index (HEI) was developed specifically to measure the adherence of dietary intake data towards Dietary Guidelines for Americans (Kennedy *et al.*, 1995), while the Mediterranean Diet Score (MDS) and its variations have been formulated and applied to assess the degree of adherence to the Mediterranean diet (Trichopoulou *et al.*, 1995, Bosetti *et al.*, 2003, Osler and Schroll, 1997).

An additional purpose of a DQI is to act as a predictor of health outcomes (Fransen and Ocké, 2008). Past formation and utilisation of DQIs have been to examine the risk of unwanted health outcomes (e.g. CVD, cancer, hypertension) though all-cause mortality (McCullough *et al.*, 2002, Waijers *et al.*, 2007, Reedy *et al.*, 2014), and associated biomarkers (Huijbregts *et al.*, 1997).

In the past, DQIs have been developed for selected population groups (Alkerwi, 2014). While most DQIs focus on adult populations (Alkerwi, 2014), they have also been developed for other target audiences such as, children (Delshad *et al.*, 2018), adolescents (Feskanich *et al.*, 2004, Wong *et al.*, 2013), and pregnant women (Bodnar and Siega-Riz, 2002). Dietary patterns are affected by food accessibility, culture, and social backgrounds (Collins *et al.*, 2015, Wirfält *et al.*, 2013). Due to the differences in these factors, and the diverse main health concerns between countries, a DQI should be country-specific (Alkerwi, 2014).

Many applications of DQIs have been identified (Alkerwi, 2014). Diet quality indices can be used as an effective health assessment method for rapid screening to assess and monitor population health status (Hu, 2002). Repeat DQI administrations over time can help identify food habit changes and compare diet quality within and between population groups (Kennedy *et al.*, 1995, Alkerwi, 2014). It has also been suggested that health professionals and dietitians extend the application of DQIs to act as a nutrition education and counselling tool for different populations (Alkerwi, 2014).

Original diet quality indices - an overview

A review of diet indices identified 25 indices targeted towards an adult population. These indices included components that were nutrients only, healthy food group variety measures, and adherence to food group serving recommendations (Wirt and Collins, 2009). The most commonly adopted and validated DQIs are, the Diet Quality Index (Patterson *et al.*, 1994), the MDS (Trichopoulou *et al.*, 1995), the HEI (Kennedy *et al.*, 1995), and the Healthy Diet Indicator (HDI) (Huijbregts *et al.*, 1997, Waijers *et al.*, 2007). The Diet Quality Index, along with the HEI and HDI were formulated to contain components that represented and assessed adherence to specific dietary recommendations (Kennedy *et al.*, 1995, Huijbregts *et al.*, 1997, Patterson *et al.*, 1994). Most of these popular indices have variations, which represent updates made to dietary guidelines over time (Waijers *et al.*, 2007). An example of this is the MDS

(Trichopoulou *et al.*, 1995), which has four distinct variations (Schröder *et al.*, 2004, Haveman-Nies *et al.*, 2002, Fung *et al.*, 2005, Pitsavos *et al.*, 2005). The MDS measures adherence to the Mediterranean diet rather than predetermined dietary guidelines (Trichopoulou *et al.*, 1995).

Unsurprisingly, the first DQI created was named the Dietary Quality Index. The purpose of this index was to assess the adherence of an adult population group to dietary recommendations from the 1989 National Academy of Sciences publication called 'Diet and Health' (Patterson *et al*., 1994). Since the creation of the Diet Quality Index, multiple indices have been created on the basis of this tool (Waijers *et al.*, 2007). One of these adaptions is the Diet Quality Index-International (DQI-I), which was successful with its aim of comparing diet quality between China and the US (Kim *et al.*, 2003). The Diet Quality Index Revised (DQI-R) was created to align with updated American dietary recommendations and to include standardised measurements of index components (Haines *et al.*, 1999).

The original HEI was developed to examine overall diet quality of the US population through a 10-component system consisting of four nutrients, five food groups, and food variety (Kennedy *et al.*, 1995). Since then other variations including the Healthy Eating Index-2005 (HEI-2005) (Guenther *et al.*, 2008), the Healthy Eating Index-2010 (HEI-2010) (Guenther *et al.*, 2008), and the most recent Healthy Eating Index-2015 (HEI-2015) (Reedy *et al.*, 2018) have taken presidency over the original HEI (Kennedy *et al.*, 1995). The HEI-2005 was necessitated due to changes made to the Dietary Guidelines for Americans 2005. This caused the new HEI-2005 to place more emphasis on caloric intake, whole grains, particular vegetable intakes and fat type (Guenther *et al.*, 2008).

The follow-up HEI-2010 was created to capture the diet quality of the US population using the Dietary Guidelines for Americans 2010 (Guenther et al., 2013). The most recent HEI-2015 was created to represent the current 2015-2020 Dietary Guidelines for Americans (Reedy *et al.*, 2018). The nine-component Alternative Healthy Eating Index (AHEI) was also formed on the foundation of the HEI. The AHEI was created to

focus on macronutrient sources and food choices related to chronic disease reduction. Research found the AHEI to be a better predictor of chronic disease risk (especially CVD) compared to the original HEI (McCullough *et al.*, 2002).

The HDI was formulated upon the WHO Guidelines for chronic disease prevention. The HDI was originally examined in a large male cohort, which showed dietary patterns to be associated with mortality (Huijbregts *et al.*, 1997). The HDI was also applied to a female population group in the United Kingdom, helping to identify independent predictive factors (age, a vegetarian diet, BMI, energy intake, and food costs) associated with healthier eating (Cade *et al.*, 1999). Later, the HDI was assessed using an Eastern European population consisting of both genders, which found diet quality to be inversely correlated to CVD mortality (Stefler *et al.*, 2014).

Diet quality indices developed for cardiovascular health

Over recent years, evidence has accumulated demonstrating the impact of dietary patterns on CVD (Kant, 2004, Katcher *et al.*, 2009). Currently, there are three known DQIs that have been specifically developed to assess CVD risk: the Dietary Quality Score (DQS) (Toft *et al.*, 2007), Diet Quality Tool (DQT) (O'Reilly and McCann, 2012), and the Food Pyramid Index (FPI) (Massari *et al.*, 2004).

The validated DQS was developed to provide a quick rough classification of diet quality and CVD risk factors (LDL-C, triglycerides, homocysteine), based upon adherence to Danish Dietary Guidelines (Toft *et al.*, 2007). The DQT was created and validated to evaluate diet quality by determining adherence to the Heart Foundation's nutrition guidelines for secondary CVD prevention within a secondary CVD prevention Australian population group (O'Reilly and McCann, 2012). Lastly, the FPI examined fat intake in relation to CHD risk factors within two Italian-based studies through adherence to the Food Pyramid dietary guidelines. Findings showed higher index scores (higher fat intake) positively correlated with all five CHD factors examined (Massari *et al.*, 2004). There is no validated or reliable NZ population-specific DQI that evaluates diet quality in relation to CVD risk. Further information on these CVD-specific DQIs can be seen in Table 2.

In the past, other DQIs not developed specifically for CVD predictability, have found associations with CVD risk, mortality, and prevention (Reedy *et al.*, 2014, McCullough *et al.*, 2002). One study (Reedy *et al.*, 2014) examined four DQIs, these were the HEI-2010 (Guenther *et al.*, 2013), AHEI-2010 (Chiuve *et al.*, 2012), Alternative Mediterranean Diet (AMED) score (Fung *et al.*, 2005), and the Dietary Approaches to Stop Hypertension (DASH) score (Fung *et al.*, 2008). This study found all indices showed participants in quintile 5 (highest diet quality) compared to quintile 1 (lowest diet quality) had a 12-28% reduced risk of all-cause CVD (Reedy *et al.*, 2014). Additionally, the AHEI has shown to have a strong inverse association with CVD, even more so than the original HEI (McCullough *et al.*, 2002). Over all, a range of diet indices have been formulated specifically and not specifically for CVD risk (Reedy *et al.*, 2014, Toft *et al.*, 2007, O'Reilly and McCann, 2012, McCullough *et al.*, 2002), but no one has been identified as the 'gold standard'.

Diet quality indices developed in New Zealand

The Diet Quality Index and original HEI are the most commonly used DQIs, which are founded upon set dietary guidelines (Patterson *et al.*, 1994, Kennedy *et al.*, 1995). However, these dietary indices and their subsequent variations have been developed based on US dietary guidelines (Newby *et al.*, 2003, Guenther *et al.*, 2008, Guenther *et al.*, 2013, Patterson *et al.*, 1994, Kennedy *et al.*, 1995, Reedy *et al.*, 2018), making them less applicable to a NZ population with altered recommended dietary guidelines (Wong *et al.*, 2013).

Current validated NZ-specific DQIs available include the New Zealand Women's Healthy Diet Index (NZW-HDI) (Fenner, 2015), the New Zealand Diet Quality Index for Adolescents (NZDQI-A) (Wong *et al.*, 2013), the Healthy Dietary Habits Score for Adolescents (HDHS-A) (Wong *et al.*, 2014), the Healthy Dietary Habits Index (HDHI) (Wong *et al.*, 2017), and the Dietary Index for a Child's Eating (DICE) (Delshad *et al.*, 2018). Each of these diet indices are targeted towards specific NZ audiences, such as the NZDQI-A and NZW-HDI which are targeted towards understanding the diet

quality of NZ-residing adolescents and women respectively (Wong *et al.*, 2013, Fenner, 2015). The only NZ-based index developed, that includes older adults, is the HDHI. However, this index does not examine CVD risk nor does it focus on the older adult age group exclusively (Wong *et al.*, 2017). Additional details of these NZ-based diet indices can be viewed in Table 2.

Table 2. Summary of original diet quality indices, CVD-specific diet quality indices, and diet quality indices created for a New Zealand population

Authors (year)	Diet quality index	Dietary guidelines or specific diet used	Participants	Validation method	Outcome measure	Components and scoring system	Primary findings
Original diet quality indices							
Patterson *et al.*, (1994)	Diet Quality Index (DQI)	1989 National Academy of Sciences publication Diet and Health dietary recommendations.	5,484 US participants, ≥21y	24-hour recall and 2-day food record	Nutrient adequacy	8-components, consisting of 2 food groups and 6 nutrients. - 0 (best) - 2 (worst) scoring range. - Total score range: 0 - 16.	Index scores were positively associated with greater intake of vitamins and minerals and inversely associated with fat intake.
Kennedy *et al.*, (1995)	Healthy Eating Index (HEI)	US Department of Agriculture Food Guide Pyramid	7,443 US participants, >2y	24-hour recall and 2-day food record	Nutrient adequacy	10-components, comprising of 5 food groups, 4 nutrients and a food variety measure. - 0 (worst) - 10 (best) scoring range. - Total score range: 0 - 100.	Positive correlation between increased range of nutrient intake and a higher index score.
Huijbregts *et al.*, (1997)	Healthy Diet Indicator (HDI)	WHO dietary guidelines for the prevention of chronic diseases	3,045 European (Netherlands, Finland, Italy) male participants, 50-70y	Diet history	All-cause mortality	9-components, including 3 food groups and 6 nutrients. - 0 (worst) - 1 (best) scoring range. - Total score range: 0 - 9.	Intake varied between European countries, specifically saturated fat, cholesterol, and alcohol intake. A greater HDI score was negatively associated with mortality.

Authors (year)	Diet quality index	Dietary guidelines or specific diet used	Participants	Validation method	Outcome measure	Components and scoring system	Primary findings
Original diet quality indices							
Trichopoulou *et al.*, (1995)	Mediterranean Diet Score (MDS)	Traditional Mediterranean diet	182 elderly Greek participants, >70y	190-item FFQ	All-cause mortality	8-components, consisting of 7 food groups and a nutrient measure. - 0 - 1 scoring range for each component. - Total score range: 0 - 8.	Index score positively associated with reduced mortality, specifically a 17% reduced mortality risk for every 1-point gained towards total 8-point index score.
CVD-specific diet quality indices							
Toft *et al.*, (2007)	Dietary Quality Score (DQS)	Danish Dietary Guidelines	6,542 Danish participants, 30-60y	198-item FFQ	Cardiovascular biomarkers	4-components, consisting of all food groups. - 1 (worst) - 3 (best) scoring range. - Total score range: 3 - 12.	A higher DQS was positively correlated to better diet quality including high fruit, vegetables, fish, specific vitamins and minerals, fibre and whole-grain consumption, and low fat (particularly saturated fat) intake. The index score was inversely associated with biomarkers of CVD risk (homocysteine, triglycerides, total cholesterol, LDL-C) and CHD risk, while adjusting for confounding variables.

Authors (year)	Diet quality index	Dietary guidelines or specific diet used	Participants	Validation method	Outcome measure	Components and scoring system	Primary findings
CVD-specific diet quality indices							
O'Reilly and McCann (2012)	Diet Quality Tool (DQT)	Heart Foundation secondary prevention nutrition guidelines	37 Australian participants (all post-CVD event), mean age: 61.2y	4DFR	Nutrient adequacy	5-components, containing 2 food groups and 3 nutrient measures. - 0 - 10, 0 - 20, 0 - 30, 0 - 50 scoring range, with a low score meaning worse dietary quality. - Total score range: 0 - 130.	A higher DQT score was inversely and positively correlated to saturated fat and omega-3 fatty acid intake respectively (construct validity). Significant differences for fibre and saturated fat intake between highest and lowest DQT scores (relative validity).
Massari *et al.*, (2004)	Food Pyramid Index (FPI)	Food Pyramid	7665 Italian-based participants, 20-59y	Not applicable	Cardiovascular biomarkers	17-components composed of all food groups. - 0 (worst) - 30 (best) - Total score range: 0 - 510.	Positive correlation between FPI scores (based on fat intake) and five CHD risk factors (blood glucose, total serum cholesterol, BMI, systolic, and diastolic blood pressure).

Authors (year)	Diet quality index	Dietary guidelines or specific diet used	Participants	Validation method	Outcome measure	Components and scoring system	Primary findings
NZ-specific diet quality indices							
Fenner (2015)	NZ Women's Healthy Diet Index (NZW-HDI)	Eating and Activity Guidelines for NZ Adults	110 NZ-based female participants, 19-45y	4DFR	Nutrient adequacy	17-components, consisting of 15 food groups and 2 food variety measures. - 0 - 5 or 0 - 10 scoring range, the lower the score the poorer dietary quality indicated. - Total score range: 0 - 115.	Index score was significantly positively associated with specific nutrient (fibre, vitamin C, calcium, and folate) intake, and inversely associated with alcohol and saturated fat intake (construct validity). Fair relative validity was also evidenced.
Wong *et al.*, (2013)	Diet Quality Index for NZ Adolescents (NZDQI-A)	NZ Food and Nutrition Guidelines for Healthy Adolescents.	41 NZ-based participants, 14-18y	FQ and 4DFR	Nutrient adequacy	5-components, comprising of all food groups. - 0 (worst) - 20 (best) scoring range. - Total score range: 0 - 100.	Higher NZDQI-A scores were positively correlated to higher fat and iron intake. Index was shown to be relatively valid (construct and relative validity) and reproducible, despite small sample size.

Authors (year)	Diet quality index	Dietary guidelines or specific diet used	Participants	Validation method	Outcome measure	Components and scoring system	Primary findings
NZ-specific diet quality indices							
Wong *et al.*, (2017)	Healthy Dietary Habits Index (HDHI)	NZ Food and Nutrition Guidelines for Healthy Adults	3,993 NZ-based participants, 19-98y	24-hour recalls, social factors and nutritional biomarkers.	Nutrient adequacy	15-components, containing all food groups. - 0 (worst) - 4 (best) scoring range. - Total score range: 0 - 60.	Higher scoring was associated with greater specific nutrient intakes (fibre, calcium, vitamin C, iron, and four other micronutrients), but lower intakes of energy, macronutrients, and sodium, vitamin B6, B12, and zinc. Acceptable construct validity was demonstrated.
Delshad *et al.*, (2018)	Dietary Index for a Child's Eating (DICE)	NZ Food and Nutrition Guidelines for Healthy Children and Young People	49 NZ-based participants, 2-8y	4DFR	Nutrient adequacy	13-components, with 11 food groups and 2 food variety measures. - 0 - 5, 0 - 10 or 0 - 15 scoring ranges; a higher score is best. - Total score range: 0 - 100	Higher index score positively correlated to increased intake of vitamin C, calcium and folate. For construct validity, a greater total index score was positively associated with selected nutrient intakes (calcium, vitamin A, C, D, and folate). Very strong reproducibility and significant relative and construct validity was shown.

Authors (year)	Diet quality index	Dietary guidelines or specific diet used	Participants	Validation method	Outcome measure	Components and scoring system	Primary findings
NZ-specific diet quality indices							
Wong *et al.*, (2014)	Healthy Dietary Habits Score for Adolescents (HDHS-A)	NZ Food and Nutrition Guidelines for Healthy Children and Young People	694 NZ-based participants, 15-18y	DHQ, 24-hour recalls, social factors and nutritional biomarkers.	Nutrient adequacy	17-components, with 4 food group clusters and 1 meal habits. - 0 (worst) - 4 (best) scoring range. - Total score range: 0 - 68.	Increased index scoring was positively correlated to fibre, PUFA, lactose, protein, and most micronutrients, while inversely associated with sucrose intake. Residing in highest socioeconomic quintile, female and non-Māori or Pacifica were linked to an elevated index score. Inadequate reliability, conservative content, and construct validity.

BMI, Body Mass Index; CHD, Coronary Heart Disease; CVD, Cardiovascular Disease; DHQ, Dietary Habits Questionnaire; DICE, Dietary Index for a Child's Eating; DQI, Diet Quality Index; DQS, Dietary Quality Score; FQ, Food Questionnaire; FFQ, Food Frequency Questionnaire; HDHI, Healthy Dietary Habits Index; HDI, Healthy Diet Indicator; HEI, Healthy Eating Index; LDL-C, Low-density Lipoprotein- Cholesterol; MDS, Mediterranean Diet Score; NZ, New Zealand; NZDQI-A, Diet Quality Index for New Zealand Adolescents; NZW-HDI, New Zealand Women's Healthy Diet Index; PUFA, Polyunsaturated Fatty Acid; US, United States; WHO, World Health Organisation; 4DFR, Four-day Food Record.

Diet quality indices development

When constructing a DQI there are key aspects to consider including, selection of index components, cut-off values and scoring criteria, possible energy intake adjustments, and the relative contribution of component scores to the total index score (Waijers *et al.*, 2007).

Selection of index components

Index components consist of nutrients, foods, and/or food groups, which are classified as either healthy or unhealthy (Waijers *et al.*, 2007, Kant, 1996). The Diet Quality Index (Patterson *et al.*, 1994), HDI (Huijbregts *et al.*, 1997), HEI (original) (Kennedy *et al.*, 1995), and DQT (McNaughton *et al.*, 2008) have both food group and nutrient components, while others like the FPI (Massari *et al.*, 2004), Food-Based Quality Index (Löwik *et al.*, 2007), and the Healthy Food Index (Osler *et al.*, 2001) use food group components only. Nutrients commonly selected as DQI components include SFA, PUFA, monounsaturated fatty acid (MUFA), total fat, alcohol, and cholesterol (Waijers *et al.*, 2007). It is evident that a focus has been placed on the composition of fatty acid consumption, as a greater intake of PUFA and MUFA has been associated with CVD risk reduction (Hammad *et al.*, 2016). Common DQI food group components are fruits and vegetables (jointly or individually) and cereals/grains (Waijers *et al.*, 2007).

Cut-off values and scoring criteria

In order to quantify (score) selected index components, each component is assigned a cut-off value (Waijers *et al.*, 2007). Cut-off values can be determined from median dietary intakes of each component in a population (Trichopoulou *et al.*, 1995), or can be selected based upon dietary guidelines. For example, simply done, if an individual's reported intake exceeds this cut-off value, a score of 'one' is designated, but if their intake is below the value a score of 'zero' is received (Waijers *et al.*, 2007).

However, if consumption of a component is deemed 'unhealthy' the reverse scoring procedure is applied (Waijers *et al.*, 2007, McNaughton *et al.*, 2008). On the other hand, some DQIs have multiple cut-off values for each component, representing lower, intermediate, and upper reported consumption levels (Patterson *et al.*, 1994, Haines *et al.*, 1999, Wong *et al.*, 2013, McNaughton *et al.*, 2008).

Energy intake adjustment

It has been recognised that individuals with a high-energy intake may more readily adhere to dietary guidelines and meet maximum component scoring criteria. As a result, individuals who exceed their energy requirements, perhaps undesirably, may still receive a high index score (Waijers *et al.*, 2007, Wong *et al.*, 2013, Willett and Stampfer, 1986). This confounding variable can be managed by proportionally scoring each component relative to their recommended energy intake determined by their sex and gender (Kennedy *et al.*, 1995, Haines *et al.*, 1999), or adjusting for energy intake.

Contribution of component scores

Most DQIs have an equal scoring contribution of all index components towards the total index score. Despite no components having an identical impact on heath, the reasoning behind the scoring has been left ambiguous (Waijers *et al.*, 2007). For example, the Australian Dietary Guideline Index (DGI) (McNaughton *et al.*, 2008) and the DQT (O'Reilly and McCann, 2012) each had 13 index components all scored from 0-10, giving equal weight of all components towards the total 130-point index score. Similarly, the DQS used a 3-point system for all four components, contributing evenly to the 12-point total score (Toft *et al.*, 2007).

New Zealand Heart Foundation dietary guidelines

The NZ Heart Foundation Guidelines are a set of dietary recommendations constructed by The National Heart Foundation of New Zealand (also called the Heart

Foundation) (Heart Foundation of New Zealand, 2018, Heart Foundation of New Zealand, 2017). This registered NZ charity was established in 1968 (Heart Foundation of New Zealand, 2019a), with the aim of preventing CVD deaths and minimizing the effects on people living with heart disease in NZ (Heart Foundation of New Zealand, 2019c).

The 2018 NZ Heart Foundation Guidelines are presented in the 'Eating for a Healthy Heart' resource, which also contains the ''Healthy heart' visual food poster guide'. This resource provides dietary information regarding CVD prevention for New Zealanders. The 2018 NZ Heart Foundation Guidelines are summarized into the 'Nine Steps to Heart-Healthy Eating', in which each step provides a dietary guideline along with specific daily serving recommendations for 'general heath' and 'heart health'. In some cases, alternative general dietary recommendations are given 'for people with diabetes' (Heart Foundation of New Zealand, 2018). The 'Nine Steps to Heart-Healthy Eating' is presented in Table 3 below, along with corresponding daily serving guidelines or general recommendations.

Table 3. The nine steps to heart-healthy eating from 'Eating for a healthy heart' from The National Heart Foundation of New Zealand

Heart Foundation guideline	General health	Heart health
Eat foods that are as close to how they would be found in nature.	-	-
Eat most vegetables and/or fruit.[1]	≥5 serves daily (vegetables: 3+ serves daily, fruit: 2+ serves daily)	Vegetables: 3-4 serves daily Fruit: 3-4 serves daily
Eat some grain foods and starchy vegetables.[1, 2]	3 serves of whole grains daily	3 serves of whole grains daily
Eat some legumes, fish, seafood, eggs, meat and poultry.	1-2 serves daily	Legumes: 4-5 times weekly, fish: twice weekly (oily preferred), chicken or lean meat: ≤1-1.5 servings daily or vegetarian replacement
Eat some milk, yoghurt and cheese [1]	≥2 serves daily	2-3 servings daily
Eat some healthy oils, nuts and seeds.	-	≥6 servings daily
Drink water and restrict sugar-sweetened beverages and alcoholic drinks.[3]	- Drink six-eight cups of fluid daily; preferably water. - Restrict sugar-sweetened beverages and alcoholic drinks intake and replace fruit juice with whole fruit. - Reduce long-term effects of alcohol intake by having ≤2-3 and ≤1-2 standard drinks for men and women respectively.	
Instead of salt and sugar, use pepper, herbs and spices to season food and drink.[3]	- Restrict salt intake where possible. - If needed, use just a pinch of iodised salt when cooking. - Replace salt with various low or no-salt herbs and spices for seasoning of food. - Pick reduced salt/sodium or no salt/sodium food options.	
Cut back on junk foods, or foods high in sugar, salt, or saturated and trans fats.[3]	- Foods include deep-fried and junk foods, takeaways, processed meats, pastries, sweet bakery products, salty, savoury and sweet snack foods. - ≤1 takeaway weekly. - Restrict foods high in trans and saturated fats, sugar, salt, low fibre and/or refined carbohydrates.	

This table was adopted from (Heart Foundation of New Zealand, 2018).
[1] Another dietary recommendation category is available for people with diabetes; [2] Dietary recommendations have changed from the 2017 Heart Foundation dietary guidelines which were, general health: 6+ servings of breads and cereals per day, heart health: 6+ serves per day with starchy vegetables; [3] General dietary recommendations.

Validation of diet quality indices

Validity is defined as to the degree to which an instrument measures what it is intended to measure (Kimberlin and Winterstein, 2008, Thompson and Subar, 2017). While each dietary assessment tool has strengths and weaknesses, no method is free of error in the measurement process (Kimberlin and Winterstein, 2008, Crocker and Algina, 1986, Thompson and Subar, 2017). This principle applies to DQIs where methodological errors can impact validity and the assessment of diet quality (Waijers *et al.*, 2007). When DQIs are going to be used in research to examine links/associations between dietary intake and health outcomes it is important they are validated to avoid inaccurate links or associations being made (Cade *et al.*, 2002, Wong *et al.*, 2013). Diet quality index validation must be conducted through independent testing, to confirm accurate measuring of what the index is intended to measure (Biró *et al.*, 2002). Generally, DQIs are validated via nutritional adequacy, or through comparison to anthropometric, biochemical, and clinical nutrition-based determinants (Kant, 1996). An alternative validation method is through evaluation against a reference method, such as a food record (Wong *et al.*, 2013). There are three different types of validity recognized, content, relative, and construct validity (Kaplan *et al.*, 1976, Kimberlin and Winterstein, 2008).

Content validity

Content validity measures qualitatively the extent components of a construct represent what they are supposed to measure (Kaplan *et al.*, 1976). This type of validity usually relies on expert judgment, as there is no statistical measurement that can be performed to accurately examine if these components sufficiently cover a desired construct (Kimberlin and Winterstein, 2008). For DQIs, content validity can be used to evaluate the extent components of an index embody a set of dietary guidelines (Guenther *et al.*, 2008). This can be achieved by comparing the components of an index to the desired dietary guidelines (Waijers *et al.*, 2007). While content validity seems to be considered in the development of DQIs, with researchers including components that represent selected dietary guidelines such as

components from the HEI-2005 (Guenther *et al.*, 2008) and HEI-2010 (Guenther *et al.*, 2013) representing Dietary Guidelines for Americans 2005 and 2010 respectively, content validity is rarely evaluated in studies (Guenther *et al.*, 2008).

Relative validity

Relative (criterion) validity is defined as the degree a result corresponds with an outcome accepted as truth (Kimberlin and Winterstein, 2008). This type of validity can be performed to assess if a recently developed DQI produces the same findings as an accepted referenced dietary assessment method, such as a food record (Wong *et al.*, 2013). It is important any DQI is validated by comparing the DQI scores to a more in-depth gold standard assessment tool, with uncorrelated errors (Lazarou and Newby, 2011). For example, the relative validity of the newly developed NZDQI-A (test method) was examined by comparing its findings to a 4DFR (reference method) (Wong *et al.*, 2013). Similarly, the relative validity of the DICE index (Delshad *et al.*, 2018) and the NZW-HDI (Fenner, 2015) were both conducted by comparison to respective nutrient data collected from 4DFRs.

Construct validity

Construct validity assesses the associations between an instrument and variables related to the instrument (Kaplan *et al.*, 1976, Kimberlin and Winterstein, 2008). This form of validity is established based upon multiple sources of evidence, such as relative and content validity contributions. Over all construct validity examines the extent to which associations can be made between known and theoretical variables and the construct an instrument is measuring (Kimberlin and Winterstein, 2008). In the context of DQIs, construct validity measures quantitatively the degree an index is measuring diet quality (Guenther *et al.*, 2008).

Often the construct validity of DQIs is evaluated by assessing the association between the observed score and favourable and unfavourable food and nutrient intakes. A high diet quality score is expected to positively correlate to a greater

desired food and nutrient intake (Wong *et al.*, 2013). For instance, the construct validity of the HEI-2005 was assessed through the analysis of four separate exemplary diet menus, which underwent the HEI-2005. This validity measurement indicated that the index successfully captured the theoretical construct of diet quality, as each exemplary menu was reflective of a high index score and hence, high diet quality (Guenther *et al.*, 2008).

Additional approaches to assess the construct validity of DQIs include using demographic information and health behaviours and status (McNaughton *et al.*, 2008, Toft *et al.*, 2007). An example of this approach was that socio-demographic factors, self-assessed health status, and health behaviours were used to assess the construct validity of the DGI. The DGI scores were found to be associated with sex, income, age, and area-level socioeconomic positioning, along with health status (waist to hip ratio), and specific behaviours (exercise and smoking) (McNaughton *et al.*, 2008).

Reproducibility of diet quality indices

Reproducibility (reliability) examines the stability of a tool through different techniques including repeated administrations upon the same population group or through the scoring of the same event (or behaviour) using the same tool (Kimberlin and Winterstein, 2008). There are three types of reproducibility used for measurement of instruments (dietary assessment tools): internal consistency, interrater reliability, and test-retest reliability (Kimberlin and Winterstein, 2008).

Internal consistency measures the equivalence between components from a tool, based upon the assumption that all components measuring the same construct are correlated (Kimberlin and Winterstein, 2008). On the other hand, interrater reliability explores the equivalence of tool scores from different participant groups. Furthermore, if a tool is to be used between different individuals or population groups, this form of reliability assesses if that tool is reliable to do so (Kimberlin and

Winterstein, 2008). For the purposes of discussing reproducibility relevant to DQIs, only test-retest reliability will be discussed further.

Test-retest reliability

Test-retest reliability is the most recognised type of reliability. This reliability evaluates the stability of the tool by administering a test to the same population at two different points in time, and then identifies the level of agreement between the two administration test score sets. The closer the score sets are, the greater the reliability evident (Kimberlin and Winterstein, 2008). The timing between DQIs administration is critical to accurately evaluate the test-retest reliability of the index. If there is a very short time interval between DQI administrations, participants may remember their original responses from the first administration. With a long time interval, significant changes to participant dietary intake may have occurred, hence significantly altering responses (Cade *et al.*, 2002, Kimberlin and Winterstein, 2008). To avoid these timing limitations, four to eight weeks is considered to be the ideal time lapse between dietary assessment tool administrations (Block and Hartman, 1989).

The time interval between DQI administrations varies between reproducibility studies (Wong *et al.*, 2013, Collins *et al.*, 2015, Newby *et al.*, 2003). The Australian Recommended Food Score (ARFS) created to reflect the Australian Dietary Guidelines, evaluated this newly developed index's test-retest reliability with an administration interval of five months (Collins *et al.*, 2015). On the other hand, the DQI-R conducted test-retest reliability with a time interval of only five-weeks (Newby *et al.*, 2003), which is the same time span as another DQI developed for preschool children adopted (Huybrechts *et al.*, 2010). The reproducibility of the NZDQI-A was assessed in an even shorter time period of only two-weeks between index administrations (Wong *et al.*, 2013).

Over all when constructing a new DQI to effectively examine associations between dietary intake and disease a number of elements need to be carefully considered

including, index component selection, cut-off values and scoring criteria, and the composition of the scoring (McNaughton *et al.*, 2008), but also how validity and reproducibility are going to be tested (Cade *et al.*, 2002). It is usually recommended that a variety of statistical analyses are used when assessing the validity and reproducibility of a dietary assessment tool (Cade *et al.*, 2002). To evaluate reproducibility and validity these analyses may include correlation coefficients, paired t-tests (or Wilcoxon ranked-signed tests), a Bland-Altman plot (Bland and Altman, 1986), cross-classification, a weighted kappa statistic determination (Cohen, 1968, Masson *et al.*, 2002), and linear contrast analysis (Wong *et al.*, 2013, Toft *et al.*, 2007, Fenner, 2015, Delshad *et al.*, 2018).

Summary of literature review

Cardiovascular disease is one of the leading causes of death in NZ (Ministry of Health, 2019a). It has been well evidenced that a heart-healthy dietary pattern can assist in CVD risk reduction (Katcher *et al.*, 2009). Dietary assessment has shifted from a focus on the impact single nutrients have on disease risk, to a whole diet approach conducted through dietary pattern analysis (Moeller *et al.*, 2007, Tucker, 2010). A whole diet approach acknowledges that nutrients are consumed in combinations, subsequently better representing real world dietary intake (Hu, 2002). Diet quality indices evaluate diet patterns/quality by assessing dietary adherence to specified dietary guidelines, types of diets, or particular health outcomes (Waijers *et al.*, 2007). Diet quality indices should be population specific (Wong *et al.*, 2013), and although there are several DQIs in NZ for younger age groups (Delshad *et al.*, 2018, Wong *et al.*, 2013), there are currently no valid or reproducible DQIs available specifically for the 65-74-year-old population residing in NZ and specific to CVD risk.

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[redacted]

Chapter Three- Research Study Manuscript

Determining the validity and reproducibility of the Healthy Heart Food Index

Abstract

Background: Diet quality is associated with cardiovascular disease (CVD) risk, and the New Zealand (NZ) Heart Foundation has produced dietary guidelines aimed at reducing CVD risk for adult New Zealanders. At present, there is no valid and reproducible diet quality index for older adults living in NZ, which focuses on CVD risk.

Aim: To develop and determine the construct validity and reproducibility of the Healthy Heart Food Index (HHFI) for measuring dietary patterns in older adults living in New Zealand.

Method: The HHFI was developed based upon NZ Heart Foundation Guidelines. To assess HHFI reproducibility, 298 community dwelling participants aged 65-74 years completed the HHFI twice approximately four-weeks apart. To validate the index, 142 of these participants completed a four-day food record (4DFR). Construct validity was explored using Spearman's correlation coefficients and linear contrast analysis of selected nutrients from the 4DFR. Spearman's correlation coefficients, Wilcoxon ranked-signed tests, cross-classification, the weighted kappa statistic, and a Bland-Altman plot were used to assess HHFI reproducibility.

Results: Mean HHFI total scores were 69.3±10.8 and 68.9±11.1 from the first and second HHFI administrations respectively. These scores were positively correlated (r= 0.662; *P*<0.001) and cross-classification showed 55.4% of participants were categorised into the same tertile and 6.3% were grossly misclassified. The weighted kappa statistic was κ= 0.43, indicating moderate agreement between HHFI total scores. For construct validity, iron (r= 0.201), vitamin C (r= 0.174), and niacin (r=

0.205) (all *P*<0.05), and protein (r= 0.277), polyunsaturated fatty acids (r= 0.236), dietary fibre (r= 0.307), vitamin E (r= 0.205), folate (r= 0.268), potassium (r= 0.246), magnesium (r= 0.300), phosphorus (r= 0.281), zinc (r= 0.276), and selenium (r= 0.222) (all *P*<0.01), were positively correlated with the HHFI total score. Saturated fat and cholesterol were negatively correlated (r= -0.097 and -0.035 respectively) with the HHFI total score, however this was a non-significant association (*P*>0.05). Linear contrast analysis showed a significant positive association between polyunsaturated fat, monounsaturated fat, dietary fibre, potassium, folate (*P*<0.05), vitamin E (*P*<0.01), and magnesium (*P*<0.005) and HHFI total scores.

Conclusion: Moderate adherence to the HHFI was shown in this population sample. Results indicate the HHFI demonstrated construct validity and good reproducibility for assessing CVD-related diet quality in older adults living in New Zealand. Further research is needed to examine the predictive validity of this index in relation to CVD risk.

Keywords: Diet quality index, validity, reproducibility, New Zealand, cardiovascular disease

Introduction

Cardiovascular disease (CVD) encompasses multiple conditions of the heart and blood vessels including stroke (or cerebrovascular disease) and coronary heart disease (CHD) (World Health Organisation, 2019), and is the leading cause of mortality, contributing to 31% of global deaths (World Health Organisation, 2017). In New Zealand (NZ), stroke and CHD jointly accounted for 22.3% of deaths in 2016 (Ministry of Health, 2019a). Ageing is a non-modifiable risk factor for CVD occurrence (Lakatta, 2002). As NZ has an ageing population (Bryant *et al.*, 2004), with the 65 years plus population predicted to grow by 200,000 from 2011 to 2021 (Stats NZ, 2000), it is likely the prevalence of CVD will rise as the numbers in this age bracket continue to increase.

Apart from ageing (Lakatta, 2002, Mikkola *et al.*, 2013), studies have shown modifiable lifestyle factors including physical activity (Kohl, 2001, Wannamethee and Shaper, 2001, Berlin and Colditz, 1990), smoking (Lakier, 1992, Ambrose and Barua, 2004), body weight (Kannel *et al.*, 1996, Dagenais *et al.*, 2005), alcohol consumption (Ronksley *et al.*, 2011, Malinski *et al.*, 2004), and dietary intake to impact on the likelihood of CVD occurrence (Katcher *et al.*, 2009). Biomarkers of CVD have been shown to be affected by the physiological mechanisms different nutrients elicit (Anderson, 2000, McGee *et al.*, 1984, Pietinen *et al.*, 1997, Mozaffarian *et al.*, 2006). A diet rich in vegetables, legumes, whole grains, fruit, low fat dairy sources, lean meats, fish, and poultry has been shown to have cardioprotective benefits and reduce the risk of CVD occurrence (Katcher *et al.*, 2009).

Recently, there has been a shift from examining the impact single nutrients or foods have on health (traditional method), to focusing on diet quality or dietary patterns (holistic approach) (Moeller *et al.*, 2007, Schulze and Hoffmann, 2007). Dietary patterns better reflect dietary intake in a real world setting (Hu, 2002), as unlike the traditional approach they acknowledge that nutrients and foods are consumed in combinations rather than in isolation, and these nutrient interactions can have synergistic, accumulative, and interactive effects (Sacks *et al.*, 2001, Schulze and Hoffmann, 2007). Subsequently dietary patterns are argued to be a more predictive measure of disease risk (Hu, 2002).

Dietary patterns can be determined using a-posteriori (empirical) (Tucker and Newby, 2004) or a-priori (theoretical) methodology through diet quality indices (DQIs) (Waijers *et al.*, 2007). Diet quality refers to the degree specific dietary habits assist in disease prevention or the extent a person's dietary intake adheres to outlined dietary recommendations (Kant, 1996). Research has demonstrated that as diet quality increases, disease risk lowers (Reedy *et al.*, 2014, McCullough *et al.*, 2002). For instance, one Danish study found biomarkers of CVD risk lowered as diet quality improved, with diet quality based on the degree of adherence to Danish Dietary Guidelines (Toft *et al.*, 2007).

A DQI is a dietary assessment tool created to produce a score and examine the extent a respondent adheres to predetermined dietary recommendations (Waijers *et al.*, 2007). A higher score typically indicates higher overall diet quality (Kant, 1996, Waijers *et al.*, 2007). Once a dietary assessment tool is created, its validity should be assessed by comparing its outcome to a reference dietary assessment method (Cade *et al.*, 2002). Assessment of reproducibility is also important, however this is rarely determined (Bountziouka *et al.*, 2011).

Two of the most validated, referenced, and adapted DQIs are the Healthy Eating Index (HEI) (Kennedy *et al.*, 1995) and the Diet Quality Index (Patterson *et al.*, 1994), both of which are based upon the United States (US) Dietary Guidelines (Waijers *et al.*, 2007). As a result, these indices are not suitable for the NZ population, as food consumption and dietary guidelines differ between countries (Wong *et al.*, 2013). The Dietary Quality Score (DQS) (Toft *et al.*, 2007), Diet Quality Tool (DQT) (O'Reilly and McCann, 2012), and the Food Pyramid Index (FPI) (Massari *et al.*, 2004) are only DQIs created to assess CVD risk specifically, however these indices are based on Danish, Australian, and US Food Pyramid dietary guidelines respectively. Currently, there are five validated NZ-based DQIs all developed to assess the diet quality of varying population groups (Wong *et al.*, 2014, Wong *et al.*, 2013, Delshad *et al.*, 2018, Wong *et al.*, 2017, Fenner, 2015). However, there is no valid or reliable NZ-specific DQI available that assesses diet quality with a particular focus on CVD risk within NZ's older population group.

Therefore, the aim of this study is to develop and assess the construct validity and reproducibility of a food-based DQI called the Healthy Heart Food Index (HHFI), which is focused on evaluating CVD risk in adults aged between 65-74 years old living in NZ.

Methods

Study Design and Population

Participants were part of the Researching Eating Activity and Cognitive Health (REACH) study, which aimed to determine dietary patterns in older adults and associations with cognitive function and metabolic health. As part of the REACH study participants completed the newly developed HHFI, which is the focus of this validation and reproducibility study.

Participants aged between 65-74 years of age living freely in the community were recruited from flyers distributed at town halls, sports clubs, gyms, and retirement villages. Participants were also recruited from radio station interviews and by word of mouth. Study participants needed to meet the following inclusion criteria: live independently, no mild cognitive impairment or colour blindness, proficient in English, no relevant neurological or psychiatric conditions, or diagnosis of stroke or traumatic brain injury, not be taking any medications that may influence findings, and lastly, have experienced no significant factors that may have changed their cognitive function or dietary intake in the past two years.

Data collection was completed in Auckland, NZ between April 2018 and February 2019, ensuring seasonal dietary changes were accounted for. All potential participants were given an information sheet explaining the study. Potential participants were screened by telephone to ensure they met the REACH study inclusion criteria and an appointment was organised at the Massey University Human Nutrition Research Centre (MUHNRC). Ethical approval for the REACH study was approved by the Massey University Human Ethics Committee: Southern A, Application 17/69. Written informed consent was received from all participants.

Each participant completed the HHFI on two separate occasions (to assess reproducibility). The HHFI was administered through SurveyMonkey. The first HHFI administration (HHFI 1) was conducted at the MUHNRC with a trained researcher

present to answer any participant questions. At this time, height (cm), and weight (kg) were determined using a stadiometer (Seca, model #213) and Wedderburn scales respectively. These variables were used to calculate the Body Mass Index (kg/m^2) of participants. At this time, additional health and demographic information was also collected by a self-administered questionnaire.

The second administration (HHFI 2) was completed approximately four weeks later by participants online at home, along with an estimated four-day food record (4DFR). Participants were instructed on how to complete their 4DFRs at home during their visit to the MUHNRC (see below for further details), and assigned when they would complete it by a research assistant. The 4DFR required participants to state what, where, and when they ate and drank food and beverages, as well as details regarding food/drink item quantities, food/drink brands used (when available), and cooking methods. Once returned, the 4DFRs were used to calculate energy and nutrient intakes.

Development of the Healthy Heart Food Index

Selection of index components

Development of the questions within the HHFI and identification of index components was based upon the NZ Heart Foundation's ''Healthy heart' visual food guide poster' and the 'Nine steps to heart healthy eating' (Heart Foundation of New Zealand, 2018). Subsequently, 13 index components were selected: 'vegetables', 'fruit', 'bread and cereals', 'starchy vegetables', 'dairy', 'oil, nuts and seeds', 'meat and its alternatives', 'treats', 'savoury snacks', 'sweetened drinks', 'takeaways', 'fat', and 'wholegrain proportions'. Examples of one standard serving size based on the NZ Heart Foundation Guidelines were provided for each question in the HHFI. The index components: savoury snacks, treats, and sweetened drinks had weekly frequency response categories, while the remaining components had daily serving response categories. Lastly, a list of relevant food options was provided for both fat

component questions for participants to select from (see Appendix C for a copy of the HHFI questions).

Scoring and cut-offs

The HHFI scoring criteria can be viewed in Table 1. Each of the 13 index components fell into a NZ Heart Foundation Guideline. Scoring criteria of index components were mostly based upon the 'general health' dietary recommendations, with the exception of the oils, nuts, and seeds component, which was based on 'heart health' dietary recommendations as no 'general health' recommendation was available. Additionally, the following components: treats, savoury snacks, takeaways, fats, and sweetened drinks were based on general dietary recommendations from the 2018 NZ Heart Foundation Guidelines (Heart Foundation of New Zealand, 2018). In addition, these guidelines provided a joint daily serving recommendation for whole grain and starchy vegetable intake as 'eat 3 serves of whole grains daily'. However, no quantifiable daily serving recommendation for starchy vegetables was provided from this statement or from the entire 2018 NZ Heart Foundation Guidelines (Heart Foundation of New Zealand, 2018). Therefore, the maximum scoring criteria for breads and cereals (whole grains) and starchy vegetables were three or more serves daily, which aligned more closely with the NZ Ministry of Health 'Food and Nutrition Guidelines for Healthy Older People' (Ministry of Health, 2013b).

The HHFI total score ranged from zero to 100, based upon the accumulation of index component scores. For each index component a maximum score was assigned to participants who adhered to the NZ Heart Foundation Guidelines (Heart Foundation of New Zealand, 2018), and participants who consumed less than one serving per day scored zero (minimum score). The exception was the following index components: treats, savoury snacks, takeaways, and sweetened drinks, which received a higher score the less consumption reported. Half of the index components were scored out of 10, while the remaining components received a maximum score of five.

Participants who responded between the maximum and minimum scoring criteria were scored proportionally. For instance, ≥2 servings daily for fruit equalled 10 points, 1 serving per day received five points, and no or ≤1 servings daily received zero points. The exception was the 'fats' index component score, which was a combined score from two HHFI questions: 'What type of oil or fat do you usually use in cooking (e.g. for frying, roasting, etc)'? and 'What type of spread do you usually use on bread?' For both questions participants were provided with a list of food options and if any of the selected responses: butter, lard, dripping, ghee, coconut oil, butter and margarine blend were reported from either or both questions, the component score was zero by default. If none of these selected responses were reported from either question, the maximum score was given (five).

Table 1. Healthy Heart Food Index components and scoring

Dietary guideline[1]	**Component and description**[2]	**Score allocation (Out of 100)**	**Minimum score criteria**[3]	**Maximum score criteria**[3]
Eat most vegetables and/or fruit	Vegetables: servings of vegetables daily[4]	10	0 or ≤1	≥3
	Fruit: servings of fruit daily[4]	10	0 or ≤1	≥2
Eat some grain foods and starchy vegetables	Breads and cereals: servings of breads and cereals daily[5]	5	0 or ≤1	≥3
	Starchy vegetables: servings of starchy vegetables daily[5]	5	0 or ≤1	≥3
	Whole grain proportion: proportion of whole grain breads and cereals consumed relative to total bread and cereal intake[4]	10	Never or not applicable	Always
Eat some legumes, fish, seafood, eggs, meat and poultry	Meat and it's alternatives: servings of legumes, fish or seafood, meat and poultry daily[4]	10	0 or <1	≥1
Eat some milk, yoghurt and cheese	Dairy: servings of milk, yoghurt or cheese daily[4]	10	0 or ≤1	≥2
Eat some healthy oils, nuts and seeds	Oils, nuts and seeds: servings of oils, nuts and seeds daily[4]	10	0 or ≤1	≥6

Limit sugar drinks	Sweetened drinks: frequency of sweetened drinks consumed weekly[4]	5	≥2	Never or ≤1
Cut back on junk foods, or foods high in sugar, salt, or saturated and trans fats	Treats: frequency of treats (biscuits, cakes, sweets, lollies, chocolate or ice blocks or puddings) consumed weekly[4]	5	≥2	Never or ≤1
	Savoury snacks: frequency of savoury snacks (i.e. potato chips) consumed weekly[4]	5	≥2	Never or ≤1
	Fats: type of cooking oil/s and spreads used on bread[4]	5	≥2	Never or ≤1
Limit intake of takeaways	Takeaways: frequency of takeaway food consumed weekly[4]	10	≥2	Never or ≤1

[1] Guidelines are from the 2018 New Zealand Heart Foundation Guidelines; [2] Healthy Heart Index is scored out of 100 points, from the accumulation of each component score; [3] Participant responses between maximum and minimum frequency or serving amounts were scored proportionally; [4] 'General health', 'heart health', or general recommendations from the 2018 New Zealand Heart Foundation guidelines was used for scoring criteria; [5] New Zealand Food and Nutrition Guidelines for Healthy Older People was adopted.

Four-day estimated food record

A 4DFR was used as the reference standard for validation of the HHFI. Participants were assigned four consecutive days including at least one weekend day to record their food and beverage intake. An instructional video created by staff from the Massey University School of Sport Exercise and Nutrition was viewed by participants, and a trained researcher was available to answer any questions about completion of the 4DFR. All participants were provided with a study pack to take home which contained a pictorial food record guide to assist in estimating meal or ingredient quantities, and a 4DFR booklet (refer to Appendix C). The 4DFR booklet provided an exemplar completed food record for additional assistance, as well as a template for participants to record their dietary intake over the four-day period. Once completed, participants posted their 4DFR via an addressed prepaid envelope provided. If any 4DFR material was missing or unclear, participants were contacted by email or phone to retrieve this information.

Dietary intakes from the 4DFRs were entered into FoodWorks Professional (version 9, 2018, Xyris Software) by trained nutritionists and student dietitians, in order to measure participant energy and nutrient intakes. To reduce any inconsistencies, checks were performed by an experienced REACH study member on all 4DFRs completed, and 5-10% of the records completed by an employed research assistant. The inconsistencies following 4DFR data entry inconsistencies were checked: incorrect food quantities or assumptions entered (i.e. not the allocated assumption from the assumptions list (see Appendix C)), additional 4DFR detail needed (food item quantity, cooking method etc.), and wrong participant information entered (e.g. body weight, height, gender, physical activity level etc.). If any inconsistences were identified, they were corrected and procedures were put in place to minimise the likelihood of that instance occurring again. Additionally, as mentioned an assumptions list was developed and used to ensure all data entry decisions were consistent (see Appendix C).

Statistical analysis

The statistical analysis software, SPSS version 25 (IBM corporation, New York, USA) was utilised to analyse the data. Data was tested for normality using visual inspection of histograms and the Shapiro-Wilk and Kolmogorov-Smirnov tests. Descriptive statistics are presented as mean ± standard deviation (SD) for normally distributed data (4DFR nutrients), median (25, 75 percentile) for non-normally distributed data and categorical data (HHFI total and component scores) are reported as frequencies.

<u>Reproducibility (test-retest reliability)</u>

Reproducibility was examined using Wilcoxon signed-ranked tests and Spearman's correlation coefficients for non-normally distributed data, while paired t-tests and Pearson's correlation coefficients were used for normally distributed data. These tests were performed to compare HHFI 1 and HHFI 2 total scores and all corresponding HHFI 1 and HHFI 2 component scores.

Cross-classification testing was conducted after total HHFI 1 and HHFI 2 scores were placed into tertiles. From this, the percentage of participants misclassified into opposite/extreme tertiles and correctly classified into the same tertiles from both HHFI administrations was determined. The weighted Kappa (κ) statistic was performed to assess the strength of agreement between HHFI 1 and HHFI 2 total scores, as well as accounting for the probability of agreement by chance (Cohen, 1968). The weighted κ statistic strength of agreement can be understood by the following: poor agreement (<0.20), fair agreement (0.21-0.40), moderate agreement (0.41-0.60), good agreement (0.61-0.80), and very good agreement (≥0.81) (Altman, 1991).

A Bland-Altman plot was created to examine the agreement between HHFI 1 and HHFI 2 total scores. Subsequently, HHFI 1 and HHFI 2 total score mean differences and the limits of agreement (mean difference ± 1.96 standard deviation) were calculated (Bland and Altman, 1986). This was formulated after a one-sample t-test showed no significant statistical difference between HHFI 1 and HHFI 2 test scores. To account for potential bias, linear regression analysis was conducted.

Construct validity

To assess construct validity, linear contrast analysis and Pearson's correlation coefficients were conducted to explore the association between the HHFI 1 total score distribution and the 4DFR energy and nutrient intakes. Total energy intake and 29 of the following nutrients derived from the 4DFRs were selected: protein, total fat, saturated fat (SFA), polyunsaturated fat (PUFA), monounsaturated fat (MUFA), cholesterol, carbohydrate, sugars, dietary fibre, vitamins C, E, B6, B12, A, thiamine, riboflavin, niacin, folate, beta carotene, and minerals potassium, magnesium, calcium, phosphorus, iron, zinc, selenium, and iodine. To determine the linear trend *P*-value, polynomial contrast of the 4DFR selected nutrients and the HHFI 1 scores separated into tertiles was employed.

Results

Participants (n= 298; 100 males, 188 females) completed both HHFI questionnaires administered. Participant demographic data is shown in Table 2. The mean age was 70.3±2.4 years and 69.4±2.6 years for males and females respectively. Over 90% of participants were of European ethnicity, and more than half were categorised as overweight (43.3%) or obese (14.4%). Additionally, most participants had either a post-secondary (39.9%) or a university (37.9%) qualification. Lastly, over one third of participants (38.3%) reported having a heart condition (e.g. angina, heart attack, heart failure) diagnosis.

Table 2. Participant demographic characteristics from the Healthy Heart Food Index reproducibility analysis.

Characteristics	**Male**	**Female**	**Total** (n= 298)
Age (years)	70.3±2.4	69.4±2.6	69.7±2.6
Sex[1]	110 (36.9)	188 (63.1)	298 (100)
Body fat percentage[1]	24.3±4.4	36.0±5.3	31.7±7.5
Height (cm)[1]	176.2±7.1	162.3±6.3	167.5±9.4
Weight (kg)[1]	83.4±14.2	67.8±12.5	73.6±15.2
BMI (kg/m^2)[1]	26.8±4.0	25.7±4.6	26.1±4.4
Ethnicity			
European	99 (90.0)	175 (93.1)	274 (91.9)
Other ethnicity	6 (5.5)	8 (4.3)	14 (4.7)
Chinese	2 (1.8)	3 (1.6)	5 (1.7)
Middle Eastern/Latin/ American/African	1 (0.9)	0 (0.0)	1 (0.3)
Indian	2 (1.8)	1 (0.5)	3 (1.0)
Pacific Peoples	0 (0.0)	1 (0.5)	1 (0.3)
Body mass index classifications[2]			
Underweight (<18.5 kg/m^2)	1 (0.9)	1 (0.5)	2 (0.7)
Normal weight (18.5-24.9 kg/m^2)	33 (30.0)	91 (48.4)	124 (41.6)
Overweight (25.0-29.9 kg/m^2)	59 (53.6)	70 (37.2)	129 (43.3)
Obese (≥30 kg/m^2)	17 (15.5)	26 (60.5)	43 (14.4)
Highest education level			
No qualification	1 (0.9)	2 (1.6)	4 (1.3)
Secondary	14 (12.7)	48 (25.5)	62 (20.8)
Post-secondary	42 (38.2)	77 (41.0)	119 (39.9)
University	53 (48.2)	60 (31.9)	113 (37.9)
Cardiovascular disease related diagnoses			
Heart condition (e.g. angina, heart attack, heart failure)	50 (45.5)	64 (34.0)	114 (38.3)
Stroke	0 (0.0)	2 (1.1)	2 (0.7)
High cholesterol	45 (40.9)	64 (34.0)	109 (36.6)

High blood pressure or hypertension	2 (1.8)	21 (11.2)	23 (7.7)

BMI, Body mass index; [1] Values are mean±SD for parametric data or frequency and (%) for categorical variables; [2] Recognised cut-off values for BMI classification.

Reproducibility

The total score mean±SD of the first HHFI administration was 69.3±10.8 and 68.9±11.1 for the second HHFI administration (mean difference 0.36±8.76). There was no significant difference between both HHFI administration total scores (*P*= 0.351) or any index component scores. A significant positive correlation coefficient of r= 0.662 (*P*<0.001) was shown between HHFI 1 and HHFI 2 total scores. Correlation coefficients showed a significant positive relationship between all HHFI 1 and HHFI 2 component scores, ranging from r= 0.165 to r= 0.699. All HHFI 1 and HHFI 2 component scores had significance of *P*<0.001, except for meat and its alternatives (P<0.005). Table 3 presents the results comparing the index component and total scores from the first and second HHFI administrations.

Table 3. Comparison of the first and second Healthy Heart Food Index administration component and total scores (n= 298)[1]

HHFI components	Mean intake (serves/d) (HHFI 1)	Mean intake (serves/d) (HHFI 2)	Mean difference (serves/d) (HHFI 1 & HHFI 2)	HHFI ideal scores	HHFI 1 scores	HHI 2 scores	Difference between HHFI 1 & HHFI 2 scores	Wilcoxon test (*P*-value)	Spearman's correlation coefficient (r)	Correlation (*P*-value)
Bread and cereal serves	2.5±1.5	2.5±1.5	0.0	5	2.0±1.3	2.0±1.3	0.0	0.951[2]	.601[3]	<0.001
Fruit serves	2.1±1.1	2.1±1.1	0.0	10	7.9±3.3	8.1±3.2	-0.2	0.275	.613	<0.001
Starchy vegetable serves	1.3±0.9	1.3±1.0	0.0	5	1.1±1.1	1.0±1.2	0.1	0.309	.461	<0.001
Vegetables serves	2.8±1.0	2.7±1.0	0.1	10	8.0±2.6	7.8±2.7	0.2	0.274	.382	<0.001
Dairy serves	1.7±0.9	1.7±0.9	0.0	10	7.0±3.7	7.1±3.6	0.0	0.954	.543	<0.001
Oil, nut and seed serves	2.5±1.5	2.4±1.5	0.1	10	4.0±2.7	3.9±2.6	0.1	0.639[2]	.445[3]	<0.001
Meat and its alternatives serves	1.5±0.5	1.5±0.6	0.0	10	9.4±2.4	9.1±2.9	0.3	0.128	.165	0.004
Frequency of treats	-	-	-	5	1.5±2.0	1.6±2.1	-0.1	0.359	.563	<0.001
Frequency of savoury snacks	-	-	-	5	4.0±1.8	4.0±1.7	0.0	0.784	.646	<0.001
Frequency of sweetened drinks	-	-	-	5	4.6±1.2	4.5±1.3	0.1	0.354	.574	<0.001
Frequency of takeaways	-	-	-	10	9.8±1.5	9.9±1.2	-0.1	0.180	.559	<0.001
Choice of fat	-	-	-	5	1.9±2.4	1.9±2.4	0.0	0.758	.699	<0.001
Whole grain proportion	-	-	-	10	8.2±2.3	8.1±2.3	0.1	0.338	.474	<0.001
Total HHFI scores	-	-	-	100	69.3±10.8	68.9±11.1	0.4	0.351	.662	<0.001

HHFI, Healthy Heart Food Index; HHFI 1, Healthy Heart Food Index - first administration; HHFI 2, Healthy Heart Food Index - second administration; [1] Values are mean±SD;
[2] Paired t-test used as data was normally distributed; [3] Pearson's correlation coefficient (r) as data was normally distributed.

Figure 1 presents the similarity of index component scores between the first and second HHFI administrations.

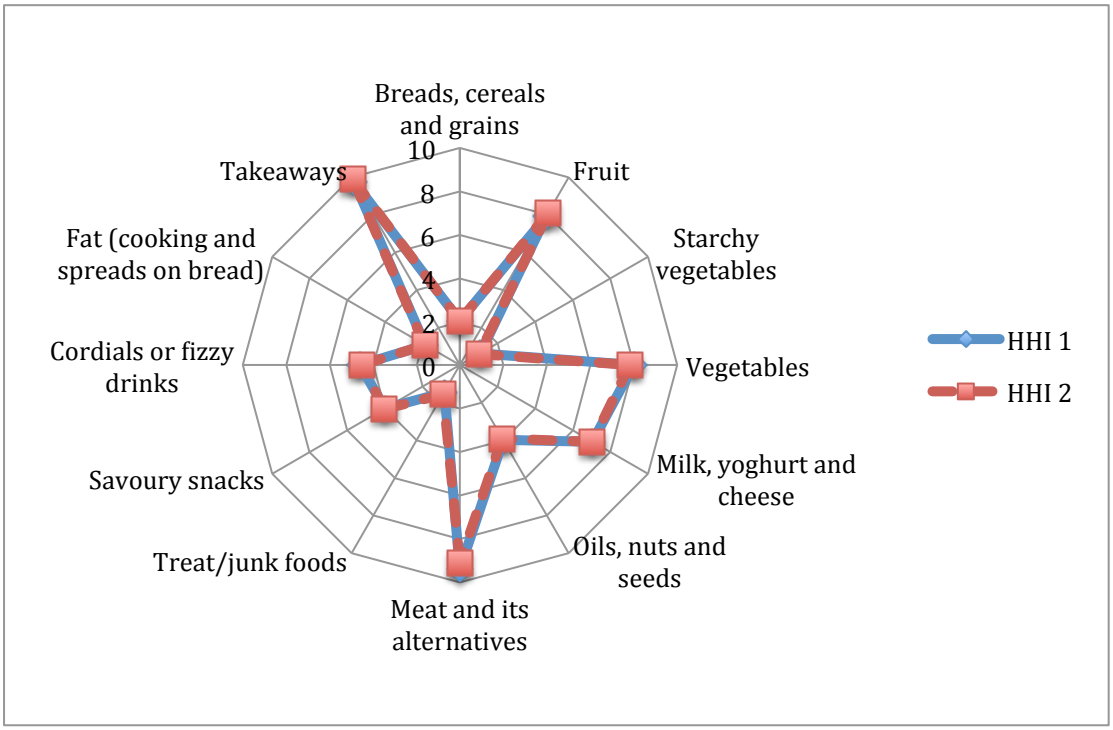

Figure 1. Radar graph comparing the first and second Healthy Heart Food Index administration component scores (n= 298)

Cross-classification results showed 55.4% of participant scores from HHFI 1 and 2 (n= 165) were allocated into the same tertile, and 6.3% of participant scores (n= 19) were misclassified into extreme tertiles. The weighted κ statistic showed a moderate agreement (κ= 0.43) between both index administration total scores.

The Bland-Altman plot (Figure 2) demonstrates the agreement between the first and second HHFI administrations. Linear regression analysis on the mean difference between both HHFI 1 and HHFI 2 administration total scores showed no proportional bias was present.

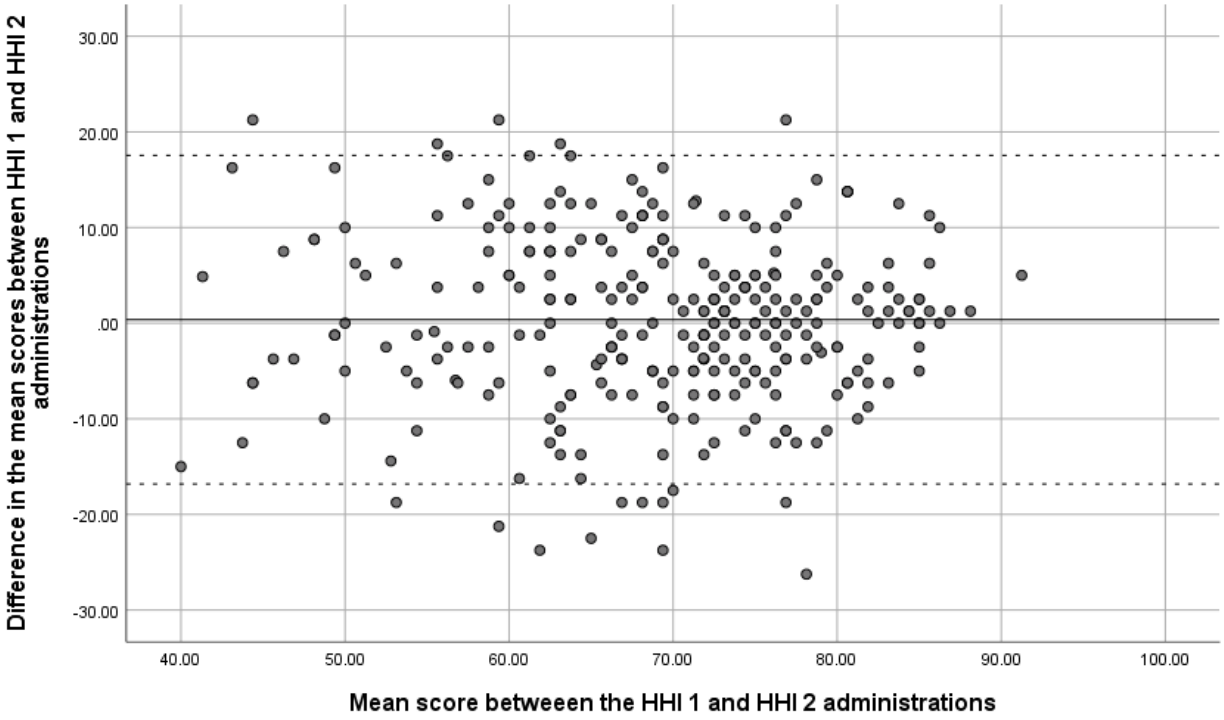

Figure 2. Bland-Altman plot presenting the strength of agreement between the mean scores and the difference in mean scores from the first and second Healthy Heart Food Index administrations (n= 298)

Construct validity

Of the 298 participants, 142 completed the 4DFR and were included in the construct validity analysis. Linear contrast analysis showed a higher intake of PUFA, MUFA, dietary fibre, potassium, folate (P<0.05), vitamin E (P<0.01), and magnesium (P<0.005) were associated with increasing tertiles of HHFI 1 total scores (Table 4).

Table 4. Nutrient intakes of 4DFR categorised by the first administration of the Healthy Heart Food Index score tertiles (n= 142)[1]

Nutrients	Tertiles of HHFI 1[2]			*P* for trend[3]
	1 (n= 43)	2 (n= 52)	3 (n= 47)	
Energy (KJ)	7916.4±1865.1	7854.0±1617.4	8422.8±1764.7	.228
Protein (g)	79.9±19.6	82.5±17.3	86.8±19.1	.216
Total fat (g)	79.3±24.3	73.4±19.7	84.4±29.3	.089[4]
Saturated fat (g)	31.0±11.4	27.3±10.0	28.9±11.9	.282
Polyunsaturated fat (g)	11.7±4.5	11.7±4.5	15.1±7.5	.004[4]
Monounsaturated fat (g)	28.1±9.3	26.3±7.7	31.4±13.3	.050[4]
Cholesterol (mg)	302.3±121.8	291.7±113.7	276.0±100.2	.532
Carbohydrate (g)	185.4±62.5	192.5±52.3	193.1±54.6	.769
Sugars (g)	83.0±37.1	92.0±32.0	91.4±31.6	.371
Dietary fibre (g)	25.3±8.3	28.5±8.4	30.6±9.5	.019
Thiamin (mg)	1.5±1.2	1.5±0.7	1.6±0.7	.775
Riboflavin (mg)	2.1±0.8	2.2±0.8	2.2±0.7	.812
Niacin (mg)	17.2±7.3	17.9±6.5	18.9±6.8	.474
Niacin equivalents (mg)	32.5±10.0	33.9±9.1	35.8±9.2	.250
Vitamin C (mg)	103.5±65.7	133.9±75.4	133.1±62.7	.060
Vitamin E (mg)	10.7±4.3	10.6±3.9	13.6±6.7	.007[4]
Vitamin B6 (mg)	2.1±1.0	2.1±0.6	2.4±1.0	.152
Vitamin B12 (µg)	3.4±1.2	4.5±36	4.7±4.4	.170[4]
Folate (µg)	386.4±162.6	454.9±172.0	468.1±163.2	.048
Vitamin A (µg)	1045.6±685.2	1139.9±886.0	1505.7±1973.2	.208
Beta carotene (µg)	4129.6±4166.6	3648.2±2243.4	4687.0±2921.9	.264
Potassium (mg)	3308.1±1025.9	3436.0±792.5	3844.8±944.2	.016
Magnesium (mg)	356.9±105.5	363.4±90.3	423.6±126.9	.005
Calcium (mg)	894.3±322.5	936.7±336.1	975.5±344.2	.519
Phosphorus (mg)	1432.7±367.4	1482.2±328.0	1605.3±402.3	.071
Iron (mg)	11.9±4.2	11.9±3.5	12.7±3.5	.478
Zinc (mg)	9.7±3.0	9.9±2.9	10.9±3.2	.110
Selenium (µg)	72.3±49.5	77.4±41.1	93.1±47.7	.081
Iodine (µg)	99.6±38.2	115.6±46.5	106.8±38.6	.175

HHFI 1, Healthy Heart Index - first administration; [1] Values are mean±SD; [2] Index tertiles divided by natural breaks in HHFI scores, therefore different participant numbers in each tertile; [3] *P*-value for trend across tertiles using linear contrast analysis; [4] *P*-value has significant homogeneity values (*P*-value<0.05).

Table 5 presents the correlations between the HHFI 1 scores and 4DFR nutrient intakes. Correlation coefficients showed statistically significant positive correlations (*P*<0.05) between HHFI 1 scores and iron (r= 0.201), vitamin C (r= 0.174), and niacin (r= 0.205). Significant positive correlations (*P*<0.01) were also shown for protein (r= 0.277), PUFA (r= 0.236), dietary fibre (r= 0.307), vitamin E (r= 0.205), folate (r= 0.268), potassium (r= 0.246), magnesium (r= 0.300), phosphorus (r= 0.281), zinc (r= 0.276), and selenium (r= 0.222). Saturated fat (r= -0.097) and cholesterol (r= -0.035) showed

inverse correlations with HHFI 1 scores, but these correlations were not statistically significant (*P*>0.05).

Table 5. Correlations between the 4DFR nutrient intakes and first administration scores from the Healthy Heart Food Index (n= 142)

Nutrients	**HHFI 1 scores**	
	Pearson's correlation coefficient (r)	**Correlation (*P*-value)**
Energy (KJ)	.126	0.134
Protein (g)	.277	0.001
Total fat (g)	.072	0.396
Saturated fat (g)	-.097	0.252
Polyunsaturated fat (g)	.236	0.005
Monounsaturated fat (g)	.121	0.150
Cholesterol (mg)	-.035	0.678
Carbohydrate (g)	.035	0.677
Sugars (g)	.041	0.626
Dietary fibre (g)	.307	0.000
Thiamin (mg)	.027	0.750
Riboflavin (mg)	.130	0.123
Niacin (mg)	.205	0.014
Niacin equivalents (mg)	.264	0.001
Vitamin C (mg)	.174	0.038
Vitamin E (mg)	.250	0.003
Vitamin B6 (mg)	.142	0.092
Vitamin B12 (µg)	.159	0.059
Folate (µg)	.268	0.001
Vitamin A (µg)	.122	0.148
Beta carotene (µg)	.159	0.058
Potassium (mg)	.246	0.003
Magnesium (mg)	.300	0.000
Calcium (mg)	.156	0.064
Phosphorus (mg)	.281	0.001
Iron (mg)	.201	0.017
Zinc (mg)	.276	0.001
Selenium (µg)	.222	0.008
Iodine (µg)	.088	0.298

HHFI 1, Healthy Heart Food Index - first administration

Discussion

From current understanding, prior to the development of the HHFI there was no reproducible or validated DQI available that assessed the diet quality and CVD risk of 65-74 year olds within the NZ population. Subsequently, the HHFI was developed and its validity and reproducibility was evaluated. Results indicate the HHFI demonstrates construct validity and good reproducibility for assessing CVD-related diet quality in older adults living in NZ.

Reproducibility (HHFI 1 scores vs. HHFI 2 scores)

Reproducibility results showed the HHFI presented good reliability through a range of statistical analysis methods conducted. To ascertain the reproducibility of the HHFI the same group of participants (n= 298) completed the HHFI twice approximately four weeks apart, and the HHFI scores were then compared. Total scores from HHFI 1 and HHFI 2 were positively correlated (r= 0.662), and there was no significant difference between total scores (*P*= 0.351). A significant positive correlation was presented from all corresponding index component scores from both the first and second administrations, with eight components presenting correlation coefficients above 0.5, and fat showing the strongest correlation (r= 0.699).

Correlation coefficients measure the relation between two administrations, but not the agreement between administrations of a tool (Bland and Altman, 1986). Consequently, a range of other statistical analyses to evaluate HHFI reproducibility were performed. These tests showed no significant differences and significant correlations between all corresponding index component scores. Cross-classification demonstrated more than 50% (55.4%) of participants were classified into the same tertile, and less than 10% (6.3%) were grossly misclassified into opposite tertiles from both HHFI administrations. Then when accounting for chance, a moderate agreement (κ= 0.43) was present between both HHFI administration total scores. These results meet recommended thresholds (Masson *et al.*, 2002). A Bland-Altman plot demonstrated the adequate agreement between the first and second administration HHFI total scores (Bland and Altman, 1986).

Despite the limitations of correlation coefficients, the majority of dietary assessment method studies have utilised this approach (Cade *et al.*, 2002). In NZ, the Diet Quality Index for NZ Adolescents (NZDQI-A) showed a positive correlation (r= 0.65) between the index administration total scores, administered two weeks apart. This finding was very similar to this study's correlation coefficient results between HHFI total scores (r= 0.662). Another NZ-based DQI called the Dietary Index for a Child's Eating

(DICE) found correlation coefficients of the DICE index components ranged from r= -0.300 to r= 1 between both index administrations. Unlike these studies mentioned (Wong *et al.*, 2013, Delshad *et al.*, 2018), this study found all corresponding HHFI index component scores (e.g. treats component HHFI 1 and HHFI 2 scores) to be both significantly and positively correlated. However, it should be acknowledged that comparison of reproducibility results between the DICE (Delshad *et al.*, 2018) and NZDQI-A (Wong *et al.*, 2013) is limited as different NZ-based population groups were used. Currently, the DQS (Toft *et al.*, 2007), DQT (O'Reilly and McCann, 2012), and the FPI (Massari *et al.*, 2004) are the only CVD-specific DQIs available. However, since the reproducibility of these indices has not been determined, reliability results cannot be compared.

Construct validity (HHFI vs. 4DFR)

Construct validity of the HHFI was demonstrated. Dietary fibre and magnesium had the strongest positive correlation between HHFI 1 total scores and 4DFR intake, followed by other nutrients including protein. This finding indicates that higher diet quality is associated with greater intakes of these nutrients, and potentially better protection against CVD risk. Rich magnesium food sources include leafy green vegetables, nuts, and grains (Abrams and Atkinson, 2003). While high dietary fibre foods include beans, barley, oats, and some fruits and vegetables (Theuwissen and Mensink, 2008).

A negative correlation was presented for cholesterol and saturated fat in relation to diet quality. While these inverse correlations were not statistically significant, this association indicates a higher score was associated with lower intakes of cholesterol and SFA. This finding aligns with the NZ Heart Foundation Guidelines, which promotes restriction of high SFA foods (coconut oil and animal-derived fats such as butter) (Heart Foundation of New Zealand, 2018).

Linear contrast analysis was performed to determine the construct validity of the HHFI, by comparing HHFI scores to selected 4DFR nutrient and energy intake data.

Results showed a significant association between seven out of the 29 4DFR nutrients (PUFA, MUFA, dietary fibre, potassium, folate, vitamin E and magnesium) and increasing HHFI tertile total scores.

Comparison of HHFI validity findings with other DQIs is limited, as no index has been created to assess CVD risk and diet quality for a NZ audience, nor for 65-74 year olds residing in NZ. As typical foods consumed in NZ differ from other countries and our food guidelines, comparison between overseas indices is restricted (Wong *et al.*, 2013). Taking this into consideration, the two CVD-specific DQIs that have evaluated construct validity are the DQS and DQT. Linear trend analysis was performed to validate the Denmark-based DQS index, after separating scores into tertiles (rather than quintiles). This study showed the intake of various micronutrients including folate, fibre, magnesium, and vitamin E were significantly positively associated with DQS score tertiles (Toft *et al.*, 2007). These results align with this study, which found a greater intake of these micronutrients to be correlated with higher tertile HHFI 1 scores. Additionally, an inverse association between SFA intake and a higher DQS score was also identified (Toft *et al.*, 2007). While not significant, this trend was also evidenced between SFA and tertiles of HHFI 1 total scores. The construct validity of the Australian DQT also demonstrated this inverse trend between SFA intake and its index score, but using logistic regression analysis after splitting total index scores into tertiles. In addition, the DQT found PUFA and dietary fibre intake to be significantly positively associated with DQT score tertiles (O'Reilly and McCann, 2012), which is a significant trend also shown in this study. Unfortunately, the construct validity of the Italian population-based FPI has not been assessed (Massari *et al.*, 2004).

In NZ, construct validity has been evaluated in several DQIs using linear contrast analysis and classification of total index scores into tertiles (Fenner, 2015, Wong *et al.*, 2013, Delshad *et al.*, 2018). However, these were in 19-45 year old women (the NZW-HDI index) (Fenner, 2015), adolescents (the NZDQI-A index) (Wong *et al.*, 2013), and children (2-8 years old) (the DICE index) (Delshad *et al.*, 2018). Using linear contrast analysis, folate was shown to be significantly positively associated with a

higher NZW-HDI total score (Fenner, 2015), and an inverse association was observed between the total NZDQI-A score and SFA intake using 4DFRs (Wong *et al.*, 2013), which both align to this study's findings. Lastly, matching this study's results, a greater fibre intake was shown to be correlated with a higher total DICE index score (Delshad *et al.*, 2018).

Strengths and limitations

Strengths of this study include the large population group recruited (n= 298, reproducibility; n= 142, construct validity) and the assessment of construct validity by comparing HHFI scores to 4DFR nutrient intakes. However, while the HHFI has demonstrated adequate construct validity, additional research is needed through longitudinal studies to establish its predictive validity of CVD risk.

Another strength of this study is the use of food-based components, which is the recommended format for diet indices (Waijers *et al.*, 2007). A strength of the HHFI itself is the inclusion of positive and negative food choices, with a reported positive food choice reflecting an increase in HHFI score, while a demerit scoring system was applied to negative food choices (savoury snacks, treats, takeaways, sweetened drinks). Furthermore, including both food choices assisted in avoiding a higher energy intake corresponding with a greater index score due to unreported high-energy foods (Wong *et al.*, 2013). Additionally, potential skewed bias responses were minimised by removing the recommended number of serves for each dietary component from the HHFI given to participants.

The use of a 'gold standard' independent dietary assessment method to assess the construct validity of the HHFI is an additional strength of this study (Thompson and Byers, 1994). Four-day food records are not dependent on memory and have lower reported errors compared to other reference methods (24-hour recall, food frequency questionnaire). However, despite additional material provided to help participants complete their records (food record guide, instructional video), food records do have a higher participant burden and self-reporting bias, which can

reduce completion rates and increase misreporting of dietary intakes (Shim *et al.*, 2014). As achieved in this study, it is ideal that the reference method (4DFR) used to assess validity is not used to create the index, as it can lead to over-estimation of validity (Lazarou and Newby, 2011).

To assess the reproducibility of a dietary assessment method, a four to eight week time interval is recommended between repeated administrations. The time period of four weeks used in this study should avoid participants remembering their previous responses, while also reducing the risk of any significant dietary changes occurring from a long time interval between administrations (Block and Hartman, 1989).

For the majority of HHFI components, scoring was done proportionately to the NZ Heart Foundation Guidelines. However, a disadvantage of this scoring method is that the NZ Heart Foundation Guidelines do not provide a quantitative measure of some components. For example, a non-quantifiable NZ Heart Foundation recommendation was 'cut back on junk foods, takeaways & foods high in sugar, salt or saturated and trans fats' (Heart Foundation of New Zealand, 2018). Stated quantifiable dietary guidelines for all components would help to avoid the subjective choices involved in scoring of the HHFI. Additionally, the NZ Heart Foundation Guidelines groups starchy vegetables and whole grain foods into the same guideline of 'eat 3 serves of whole grains daily'. However, there is no definitive quantifiable statement on daily servings of starchy vegetables, only whole grains- 'eat 3 serves of whole grains a day' (Heart Foundation of New Zealand, 2018). As a result, an external dietary guideline from the NZ 'Food and Nutrition Guidelines for Healthy Older People' was used (Ministry of Health, 2013b). In the future an exact serving for starchy vegetables in the NZ Heart Foundation Guidelines would be beneficial to increase the HHFI accurately reflecting the NZ Heart Foundation Guidelines (Heart Foundation of New Zealand, 2018).

Another improvement that could be made is redesigning the response categories and serving size examples available for each question to better represent the current 2018 NZ Heart Foundation Guidelines (Heart Foundation of New Zealand, 2018).

During the time period of HHFI development, only the 2017 guidelines (Heart Foundation of New Zealand, 2017) were available but since then the updated 2018 NZ Heart Foundation Guidelines have been released. To stay relevant to current dietary recommendations the HHFI should be adjusted to include the up to date guidelines (Heart Foundation of New Zealand, 2018).

Nutrient intake from the 4DFRs was not adjusted for energy intake to allow for nutrient intakes to be independent of energy. Subsequently, energy intake may have influenced nutrient intakes shown, and hence, construct validity findings (Willett and Stampfer, 1986). Finally, the majority of participant recruitment occurred in Auckland, NZ, all participants were volunteers, only 14.4% were obese (compared with 30.9% of the population for this age group) (Ministry of Health, 2019b) and there was an over-representation participants of European ethnicity. The findings of this work are therefore arguably not representative of 65-74 year olds nationally.

Due to the current and predicted continued growth of the 65 year and over population in NZ (Stats NZ, 2000), dietary assessment tools applicable to this age group are required to assess CVD risk. At present, the DQS (Toft *et al.*, 2007), DQT (O'Reilly and McCann, 2012), and the FPI (Massari *et al.*, 2004) are the only indices available that examine CVD risk specifically. However, these indices are based on dietary guidelines outside of NZ (Toft *et al.*, 2007, Massari *et al.*, 2004, O'Reilly and McCann, 2012), and hence, not applicable to a NZ population (Wong *et al.*, 2013). Therefore, the HHFI may fill this void and have beneficial uses including being used in epidemiological studies to examine CVD risk in relation to dietary intake among older adults in NZ. Additionally, in practice the HHFI could be used as a rapid screening tool used by healthcare professionals (e.g. registered dietitians) to assess for diet-related CVD risk among the NZ older adult population group (Alkerwi, 2014). Alternatively, the HHFI could be used for monitoring and surveillance purposes to assess the dietary intake of this population group in NZ long-term, or for more effective public diet and nutrition interventions.

Conclusion

Overall, this study has determined the HHFI has construct validity and has good reproducibility. Further work is needed to assess the extent this index can predict CVD risk within the 65-74 year old population group residing in NZ. Additionally, updates need to be made to the index itself to ensure its alignment with current NZ Heart Foundation Guidelines.

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Chapter Four- Conclusion and Recommendations

Overview of study aim and objectives

The aim of this study is to develop and assess the construct validity and reproducibility of the Healthy Heart Food Index (HHFI), which is focused on evaluating diet related CVD risk in adults aged between 65-74 years old living in New Zealand (NZ). The three study objectives were, to develop the scoring and cut-off criteria for the HHFI based on NZ Heart Foundation Dietary Guidelines; examine the construct validity of the HHFI using four-day food record (4DFR) nutrient intakes; and determine the reproducibility of the HHFI through repeat administrations to the same population group.

Achievement of study aim and objectives

The first study objective was achieved by the development of the following for the HHFI: selection of index components, development of scoring criteria, and discerning the relative contribution of index component scores to the total HHFI score (see Chapter 3, Table 1). All of these elements were based upon the 2018 Heart Foundation Guidelines (Heart Foundation of New Zealand, 2018), apart from the 13 HHFI questions themselves (including serving size examples) which were formulated upon the 2017 NZ Heart Foundation Guidelines (Heart Foundation of New Zealand, 2017). This discrepancy was because the updated 2018 guidelines were yet to be released at the time of HHFI question construction (Heart Foundation of New Zealand, 2018).

Results showed this population group had total HHFI scores of 69.3±10.8 and 68.9±11.1 for the first and second HHFI administrations respectively. These HHFI scores suggest this participant group has reasonable adherence (>50%) to the 2018 NZ Heart Foundation Guidelines (Heart Foundation of New Zealand, 2018).

Results reflecting the second study objective (construct validity of the HHFI) showed 13 nutrients from the 4DFRs had a significant positive correlation with HHFI total scores. These nutrients were: iron, vitamin C, niacin, protein, dietary fibre, vitamin E, folate, potassium, magnesium, phosphorus, zinc, and selenium. Saturated fat and cholesterol also presented a non-significant inverse association with HHFI scores. This finding aligns with the 2018 NZ Heart Foundation Guidelines, which promotes intake of foods high in many of these nutrients (fruit, vegetables, whole grains, fish, lean meats, healthy oils, nuts and seeds) and restricted intakes of saturated fat (Heart Foundation of New Zealand, 2018). Linear contrast analysis showed greater intakes of polyunsaturated fat, monounsaturated fat, dietary fibre, potassium, vitamin E, magnesium, and folate were correlated with higher HHFI total scores. These findings indicate that as total HHFI scores and diet quality increases so does the intake of these nutrients associated with reduced cardiovascular disease (CVD) risk.

The third study objective (reproducibility of the HHFI) showed a significant positive correlation and no significant difference between the total scores and corresponding index component scores from both HHFI administrations. Cross-classification showed >50% of participants were classified into the same tertile of total scores, while <10% were allocated into extreme tertiles (misclassified). These findings are ideal as they indicate the likelihood of the positive correlation between the first and second administration of the total HHFI scores being false is minimal (Masson *et al.*, 2002). A Bland-Altman plot showed adequate agreement between total HHFI scores (Bland and Altman, 1986), and a weighted Kappa statistic presented moderate strength of agreement between total scores from both HHFI administrations (Altman, 1991), when accounting for the possibility of chance (Cohen, 1968). In sum, good reproducibility of the HHFI has been indicated from these statistical analyses, even when accounting for the possibility of chance and the risk of a false association between HHFI total scores.

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Study contribution and impact

Based upon current knowledge, there is no valid or reproducible diet quality index (DQI) that is specific to the 65-74 year old population living in NZ, and/or that uses the 2018 NZ Heart Foundation Guidelines to assess dietary adherence and CVD risk within this population group. The dietary guidelines used to assess diet quality in all three known CVD-specific DQIs (Massari *et al.*, 2004, O'Reilly and McCann, 2012, Toft *et al.*, 2007) are not applicable to a NZ audience, as they are not based on NZ dietary guidelines, nor do they reflect typical food choices made by the NZ population (Wong *et al.*, 2013). As previously explained (Chapter 2), the ageing population in NZ (Bryant *et al.*, 2004, Stats NZ, 2000) will likely lead to increased CVD-related events (Lakatta, 2002) and dietary intake is a known modifiable risk factor of CVD occurrence (Katcher *et al.*, 2009, Freeman *et al.*, 2017). Therefore, having a simple, accurate (proven validity and reproducibility) dietary assessment tool, to evaluate the dietary intake and diet quality of NZ's older adults in relation to CVD risk could be particularly useful.

DQIs (such as the HHFI) have multiple purposes including, being used to evaluate dietary pattern associations and health outcomes in epidemiological studies (McCullough *et al.*, 2000, Harnack *et al.*, 2002), monitoring and surveillance of dietary intakes, trends, and compliance to dietary guidelines (2018 Heart Foundation Guidelines), and assistance in effective public health diet-related messages (Rafferty *et al.*, 2002). The HHFI specifically could be implemented as a quick dietary assessment tool to indicate CVD risk among 65-74 year old patients in dietetic or medical practices. Alternatively, dietary information gained from the HHFI could be used to inform and/or develop more effective and targeted public dietary interventions aimed at the ageing population in NZ. Subsequently, this may help to more effectively prevent and reduce CVD occurrence in this population group.

Study strengths

Study strengths include, the large population recruited (reproducibility, n= 298; construct validity, n= 142), the assessment of construct validity by comparison to an independent 'gold standard' reference method (4DFR nutrient intakes) (Cade *et al.*, 2002, Lazarou and Newby, 2011), and the use of food-based index components for the HHFI (preferred component format) (Waijers *et al.*, 2007).

The presence of both positive and negative food choices within the HHFI helped to reduce any association between a higher index score being due to 'unhealthy' food choices (Wong *et al.*, 2013). Furthermore, positive food choices (e.g. fruit and vegetable components) corresponded with increased points, while negative or 'unhealthy' food choices (e.g. takeaways, sweetened drink components) scored lower points as the intake reported increased.

Study limitations

The first limitation is that the HHFI was developed using the 2017 NZ Heart Foundation Guidelines (Heart Foundation of New Zealand, 2017), while HHFI scoring and cut-offs reflect the updated 2018 version of these guidelines. This difference in dietary guidelines occurred because the 2018 NZ Heart Foundation Guidelines were yet to be released at the time of HHFI development (Heart Foundation of New Zealand, 2018). It is important DQIs are updated to reflect current dietary recommendations, as they should represent what is presently viewed as a healthy diet (McNaughton *et al.*, 2008). Despite this limitation, only a few components were affected by this inconsistency including breads and cereals and starchy vegetables.

Some of the 2018 Heart Foundation Guidelines did not provide quantifiable dietary recommendations for particular HHFI components. For instance, 'cut back on junk foods, takeaways & foods high in sugar, salt or saturated and trans fats' was a recommended dietary intake statement (Heart Foundation of New Zealand, 2018). Therefore, subjective choices on scoring criteria and cut-offs had to be made for

takeaway, savoury snacks, and treat HHFI components. Non-quantifiable recommendations were also present for the starchy vegetables index component as only 'eat 3 serves of whole grains a day' was presented as the recommendation in the 2018 NZ Heart Foundation Guidelines to cover both whole grain and starchy vegetable intake (Heart Foundation of New Zealand, 2018). Subsequently, external NZ dietary guidelines from the 'Food and Nutrition Guidelines for Healthy Older People' was used to establish the ideal daily starchy vegetable intake for older NZ adults. Based upon these external guidelines, three or more servings daily became the established scoring criteria and maximum cut-off for starchy vegetables (Ministry of Health, 2013b). To ensure consistency of dietary recommendations, it would have been ideal if all 2018 NZ Heart Foundation Guidelines were used for all index component scoring criteria and cut-offs (McNaughton *et al.*, 2008).

Another limitation of this study is that while theoretically findings indicate a higher HHFI score corresponds to a lower CVD risk, the predictive validity of the index has yet to be determined. Further longitudinal research of HHFI as a predicator of CVD occurrence would be an area of future study to explore.

A study design limitation was the long time period between participant 4DFR completion and 4FDR data entry, in some cases up to nine months. This long interval may lead to participants being less likely to remember the exact details of their recorded intake when they were queried for additional food record information. Consequently, incorrect dietary intake assumptions (food quantity, brand, cooking method) may have been made, which could have affected the accuracy of the 4DFRs. The accuracy of the HHFI construct validity may have been reduced as a result. Additionally, it should be acknowledged that 4DFRs have multiple limitations including self-reporting bias and greater participant burden, which may have also affected 4DFR nutrient intakes reported (Biró *et al.*, 2002, Shim *et al.*, 2014). Lastly, nutrient intakes from the 4DFRs were not adjusted for energy intake. This may have led to high 4DFR nutrient values being solely due to high energy consumption instead of nutrient intake values relative to energy intake (Willett and Stampfer, 1986).

Recommendations

Based upon the limitations discussed above and for future HHFI research, the following is a list of recommendations:

- Update the HHFI to reflect the current 2018 Heart Foundation dietary guidelines (Heart Foundation of New Zealand, 2018). This includes alterations to the response categories and serving size examples presented some HHFI questions. An example of the recommended changes can be found in Appendix C.

- All aspects of the HHFI should be altered to reflect any future changes made to the NZ Heart Foundation Guidelines. Following alterations, the construct validity and reproducibility of the HHFI should be reassessed.

- Establish total HHFI score cut-offs in order to define a poor, medium versus high diet quality. This could allow for a clear HHFI score framework to help identify people according to low versus high diet-related CVD risk based upon their total HHFI score.

- Future research should assess the predictive validity of the HHFI and CVD risk, as this association has not been established.

- Should construct validity of the HHFI be re-examined, the time period between participant 4DFR completion and data entry should be reduced. This would help avoid additional assumptions made during the 4DFR data entry process, when/if participants forget their dietary intake during this time period or change their habitual dietary intake and further information is needed. Reducing this time period may also increase the accuracy of the 4DFR nutrient intakes reported and hence, improve the accuracy of the HHFI's construct validity.

- During statistical analysis, energy adjustment of nutrient intake in the 4DFR would help ensure excessive energy intake does not influence the 4DFR nutrient values presented. Furthermore, consideration needs to be made to high index scores not reflecting better diet quality, rather high energy intake alone.

- The updated HHFI should be assessed on a more diverse population. Over 90% of participants identified as European and over 75% held a post-secondary or university qualification. Having a more diverse ethnic population group and participants with various literacy levels would help indicate how valid and reproducible the HHFI is at evaluating diet quality on a population group more representative of NZ older adults, and how appropriate the HHFI is for all literacy levels.

- Assessing the validity of the HHFI according to recommendations for those at high risk of CVD, rather than just the general dietary guidelines. This may indicate how accurate the HHFI is at evaluating adherence to CVD-focussed dietary recommendations.

- Conducting research to assess the relationship between HHFI diet quality results and individual HHFI component scores and heart health among older NZ adults.

- Examining how effective the HHFI and the NZ CVD Risk Calculator work in conjunction. For example, how well these tools work together in a clinical setting for predicting CVD risk among NZ older adults.

Conclusion

In conclusion, no DQI currently exists that explores diet quality specifically in 65-74 year olds residing in NZ. Furthermore, as the NZ population continues to age (Stats NZ, 2000), the HHFI may offer a simple, country-specific, and effective method to

examine the diet quality of older adult New Zealander's based on NZ Heart Foundation Guideline adherence, with a focus on CVD risk. The HHFI showed good reproducibility, with significant associations demonstrated between HHFI first and second administration total and index component scores. The construct validity of the HHFI was also established, with higher adherence to the HHFI associated with higher intakes of nutrients protective against CVD risk.

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Harriet Guy
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Appendix

Appendix C - Questionnaire and other material used in conducting this study

Healthy Heart Food Index

The Healthy Heart Food Index (HHFI) was administered to participants through a computerized format (SurveyMonkey). To answer each question, participants were required to select one or more boxes, depending upon the question, with each box representing a possible response. Two questions may have required participants to elaborate and type in their responses.

Shown below is a reformatted version of the computerized HHFI:

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

A serving is 1 slice bread, ½ cup cooked rice or pasta

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

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

2. On average how many servings of fruit (fresh, frozen, canned or stewed) do you eat per day? Do not include fruit juice or dried fruit.

A serving is 1 medium, ½ cup cooked fruit, 1 cup raw fruit

E.g. 1 medium apple + 2 small apricots + ½ cup stewed fruit = 3 servings.

☐ Never, I don't eat fruit

☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 servings
☐ 4 or more servings
☐ Don't know

3. On average how many servings of starchy vegetables (e.g. potato, taewa (Māori potato), kumara, sweetcorn, parsnip, yam (Pacific or NZ), taro, cassava, green banana) do you eat per day?

A serving is 1 small, ½ cup cooked vegetables, 1 cup raw vegetables

E.g. 2 small potatoes + 1/2 cup sweetcorn = 3 servings

☐ Never, I don't eat starchy vegetables
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 servings
☐ 4 or more servings
☐ Don't know

4. On average how many servings of other vegetables do you eat per day?

A serving is 1 medium, ½ cup cooked vegetables, 1 cup raw vegetables

E.g. 1 medium tomato + ½ cup cooked peas + 1 cup lettuce leaves + = 3 servings.

☐ Never, I don't eat vegetables
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 servings
☐ 4 or more servings
☐ Don't know

5. How many servings of milk, yoghurt or cheese do you eat per day?

A serving is 1 glass milk, 1 pottle yoghurt, 3 Tbsp grated cheese

E.g. 1 glass of milk + 6 Tbsp cheese = 3 servings (3 or more servings)

☐ Never, I don't eat milk, cheese or yoghurt
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings

☐ 3 or more servings
☐ Don't know

6. How many servings of oils, nuts and seeds do you eat per day (this includes those used in meals)?

Includes vegetable oil, avocado, nuts and spreads or oils based on nuts (eg. peanut butter) (do not include Nutella, coconut oil, palm oil)

A serving is 1 tsp margarine or oil, 1 Tbsp nuts and seeds, 1 Tbsp avocado

E.g. 4 tsp margarine + 1 Tbsp nuts and seeds = 5 servings

☐ Never, I don't eat oils, nuts and seeds
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 servings
☐ 4 servings
☐ 5 servings
☐ 6 or more servings
☐ Don't know

7. On average how many servings of legumes, fish, seafood, eggs, poultry and meat do you eat per day?

Poultry and meat includes beef, lamb, venison, pork, chicken, turkey, mutton bird
Legumes includes baked beans, chilli beans, kidney beans, chickpeas, lentils, split peas, dahl, falafel, hummus, soybeans, tofu
Fish and seafood includes canned fish, eel, toheroa, kina, koura, paua, mussels, oyster, prawns, scallops, squid, crayfish

A serving is 1 cup cooked legumes, 1 large fish fillet, 1 cup mussels, ½ cup tuna, 1 egg, ½ cup mince, 100-120g meat or chicken, 2 chicken drumsticks

E.g. 1 cup mince = 2 servings

☐ Never, I don't eat legumes, fish, seafood, eggs, poultry and meat
☐ Less than one serving per day
☐ 1 serving
☐ 2 or more servings
☐ Don't know

8. How often do you have biscuits, cakes, sweets, lollies, chocolate or ice blocks or puddings (eg. fruit pies, crumbles, sponge puddings, steamed puddings)?

☐ Never
☐ Less than once per week
☐ Once per week
☐ 2 or more times per week
☐ Don't know

9. How often do you have cordials or fizzy drinks (do not include diet or low calorie varieties)?

☐ Never
☐ Less than once per week
☐ Once per week
☐ 2 or more times per week
☐ Don't know

10, How often do you eat savoury snacks such as potato chips?

☐ Never
☐ Less than once per week
☐ Once per week
☐ 2 or more times per week
☐ Don't know

11. How often do you have takeaway foods such as KFC, McDonalds, Burger King, deep fried food (e.g. battered fish, chicken, spring rolls), curries, commercial burgers, pizza, mince pies, sausage rolls, pastries, hot chips or wedges?

☐ Never
☐ Less than once per week
☐ Once per week
☐ 2 or more times per week
☐ Don't know

12. What type of oil or fat do you usually use in cooking (eg. for frying, roasting, etc)? Please select all that apply.

☐ Butter
☐ Lard, dripping, ghee
☐ Coconut oil
☐ Olive oil, canola oil, avocado oil, soybean oil, peanut oil, rice bran oil
☐ Sunflower oil, corn oil, safflower oil, cottonseed oil, sesame seed oil, grapeseed oil
☐ Other oil or fat (please state)
☐ I don't use oil or fat in cooking

☐ Don't know

13. What type of spread do you usually use on bread?

☐ Butter (all varieties)
☐ Monounsaturated fat margarine (eg. spreads based on olive oil, rice bran oil, canola oil)
☐ Polyunsaturated fat margarine (eg. spreads based on sunflower oil)
☐ Light monounsaturated fat margarine (eg. Olivio Spread Light)
☐ Light polyunsaturated fat margarine (eg. Flora Spread light)
☐ Plant sterol enriched margarine – both full and low fat varieties (eg. ProActive, Logical)
☐ Butter and margarine blend (eg. Country Soft, Butter Lea)
☐ Other (please state)
☐ I don't use spreads on bread
☐ Don't know

14. How often do you choose whole grain breads and cereals (e.g. whole grain or multigrain breads, porridge or oats, oatmeal, oat flakes, bran based breakfast cereals, brown rice, wholemeal pasta, quinoa, buckwheat, food made with wholegrain, whole wheat or rye flour; food made from wheat flakes, whole barley, bulgur wheat) rather than more refined breads and cereals? (e.g. white breads, cornflakes, rice bubbles, white rice, white pasta, food made with white flour)

☐ Never
☐ Rarely (1/4 of the time)
☐ Sometimes (1/2 of the time)
☐ Usually (3/4 of the time)
☐ Always
☐ Not applicable – I don't eat breads and cereals
☐ Don't know

Harriet Guy
[redacted]

Healthy Heart Food Index - recommended changes

Below presents the recommended changes to be made to selected questions from the HHFI to represent the updated 2018 NZ Heart Foundation Guidelines. The index questions not included below meet current 2018 NZ Heart Foundations Guidelines.

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

A serving is 1 slice bread, 1/3 cup cooked rice or pasta, ½ cup of cooked porridge

E.g. 4 slices bread + 1 cup of cooked porridge= 6 servings

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

2. On average how many servings of fruit (fresh, frozen, canned or stewed) do you eat per day? Do not include fruit juice or dried fruit.

A serving is 1 medium apple, ½ cup cooked fruit, 1 cup raw fruit

E.g. 1 medium apple + 2 small apricots + ½ cup stewed fruit = 3 servings.

☐ Never, I don't eat fruit
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 servings
☐ 4 or more servings
☐ Don't know

3. On average how many servings of starchy vegetables (e.g. potato, taewa (Māori potato), kumara, sweetcorn, parsnip, yam (Pacific or NZ), taro, cassava, green banana) do you eat per day?

A serving is 1 small potato or 1 small round taro

E.g. 2 small potatoes + 1 small kumara = 3 servings

☐ Never, I don't eat starchy vegetables
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 servings
☐ 4 servings
☐ 5 servings
☐ 6 or more servings
☐ Don't know

4. On average how many servings of other vegetables do you eat per day?

A serving is 1 carrot, ½ cup cooked vegetables, 1 cup raw vegetables

E.g. 1 medium tomato + ½ cup cooked peas + 1 cup lettuce leaves= 3 servings.

☐ Never, I don't eat vegetables
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 servings
☐ 4 or more servings
☐ Don't know

5. How many servings of milk, yoghurt or cheese do you eat per day?

A serving is 1 glass milk, 1 pottle yoghurt, 3 Tbsp grated cheese

E.g. 1 glass of milk + 3 Tbsp cheese = 2 servings

☐ Never, I don't eat milk, cheese or yoghurt
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 or more servings
☐ Don't know

6. How many servings of oils, nuts and seeds do you eat per day (this includes those used in meals)?

Includes vegetable oil, avocado, nuts and spreads or oils based on nuts (eg. peanut butter) (do not include Nutella, coconut oil, palm oil)

A serving is 1 tsp oil, 1 Tbsp seeds (sunflower, sesame) or avocado, 1 dessertspoon nuts or pumpkin seeds

E.g. 4 tsp oil + 1 Tbsp sunflower seeds + 1 dessertspoon of nuts = 6 servings

☐ Never, I don't eat oils, nuts and seeds
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 servings
☐ 4 servings
☐ 5 servings
☐ 6 or more servings
☐ Don't know

7. On average how many servings of legumes, fish, seafood, eggs, poultry and meat do you eat per day?

Poultry and meat includes beef, lamb, venison, pork, chicken, turkey, mutton bird
Legumes includes baked beans, chilli beans, kidney beans, chickpeas, lentils, split peas, dahl, falafel, hummus, soybeans, tofu
Fish and seafood includes canned fish, eel, toheroa, kina, koura, paua, mussels, oyster, prawns, scallops, squid, crayfish

A serving is 1 cup cooked legumes or cooked dried beans, 2 eggs, 2 small fish fillets,, ½ cup mince, 1 small skinned chicken breast, 2 slices of cooked lean meat, 100g lean steak.

E.g. ½ cup mince + 2 eggs= 2 servings

☐ Never, I don't eat legumes, fish, seafood, eggs, poultry and meat
☐ Less than one serving per day
☐ 1 serving
☐ 2 servings
☐ 3 or more servings
☐ Don't know

Harriet Guy
[redacted]

Four-day food record booklet

MASSEY UNIVERSITY
COLLEGE OF HEALTH
TE KURA HAUORA TANGATA

The REACH (Researching Eating Activity and Cognitive Health) Study

4 Day Food Record

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

If you have any questions, please contact Owen Mugridge on (09)2136650; or email reachstudy@massey.ac.nz

Harriet Guy
[redacted]

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

What to do?

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

_____

_____

_____

_____

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

Describing Food and Drink

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

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

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

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

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

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

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

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

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

Harriet Guy
[redacted]

Recording the amounts of food you eat

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

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

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

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

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

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

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

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

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

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

Harriet Guy
[redacted]

Example day

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

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[redacted]

Date_____ DAY 1

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

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[redacted]

Date_____ DAY 1 continued

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

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[redacted]

Recipes (Day 1)

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[redacted]

Additional four-day food record material

The following material was supplied to participants in their 4DFR pack to take home.

Some quick questions before you start:

Please tell us about your pantry staples

	Most used brand	What we want to know
Salt		Iodised Yes / No
Butter / Margarine / Spread		Salted / unsalted % of saturated fat (if stated)
Bread		Sliced – thin / thick
Milk (or milk alternative)		Yellow, green, lite blue, blue, silver top
Oil		Cooking and for salad?
How do you make your cup of tea?		Milk? how much? Sugar? how much? Size of cup / mug (ml)
How do you make your coffee?		Milk? how much? Sugar? how much? Caffeinated / decaffeinated Size of cup / mug (ml)
Anything else:		

Harriet Guy
[redacted]

Four-day food record assumption summary

Table 1. A summary of the assumptions record used to enter the four-day food records onto FoodWorks

Food item	Example/brands/details	Correct substitution[1]	Database[2]
Grains			
Bagel	If brand unspecified	Bagels, white, plain	NZ FoodFiles
Mixed grain bread	Generic/supermarket brands (e.g. value)	Bread, mixed grain, light, sliced, prepacked	NZ FoodFiles
Rolled oats	Generic/supermarket brands (e.g. value)	Oats, rolled, raw	NZ FoodFiles
Wholegrain oats	Generic/supermarket brands (e.g. value)	Oats, wholegrain, raw	NZ FoodFiles
White bread	If brand unspecified	Bread, white, sliced, prepacked	NZ FoodFiles
White flour	Generic	Flour, wheat, white	NZ FoodFiles
Wholemeal bread	Generic/supermarket brands (e.g. value)	Bread, wholemeal, toasted	NZ FoodFiles
Wraps	If brand unspecified	Bread, pita, white	NZ FoodFiles
Sourdough bread	-	Bakerboys White Sourdough	AusBrands 2017
Fruits			
Apricot	Raw	Apricot, raw	AusBrands 2017
Avocado	Raw	Avocado, flesh, raw	NZ FoodFiles
Banana	Generic	Banana, yellow, ripened, raw	NZ FoodFiles
Blueberry	Frozen	Blueberry, frozen	NZ FoodFiles
	Raw	Blueberry, raw	NZ FoodFiles
Kiwifruit	Green variety	Kiwifruit, zespri, green (Hayward), kiwifruit, zespri, raw	NZ FoodFiles
	Gold variety	Kiwifruit, zespri, Gold (Hort16A), kiwifruit, zespri, raw	NZ FoodFiles
Lemon juice	-	Juice, lemon, raw	NZ FoodFiles
Mango	Raw	Mango, flesh, raw	NZ FoodFiles
Vegetables			
Broccoli	Raw	Broccoli, raw	NZ FoodFiles
	Boiled/streamed	Broccoli, boiled, drained, no salt added	NZ FoodFiles
Carrot	Raw	Carrot, flesh, fresh, raw	NZ FoodFiles
Garlic	-	Garlic, cloves, raw, peeled	NZ FoodFiles
Mushroom	Fresh/stir fried	Mushroom, raw	NZ FoodFiles
Tomato	-	Tomato, whole, raw	NZ FoodFiles

Food item	Example/brands/details	Correct substitution[1]	Database[2]
Dairy			
Biofarms acidophilus organic yoghurt	-	Yoghurt, plain, unsweetened	NZ FoodFiles
Blue top milk	Generic- if no brand is available	Milk, cow, standard 3.3% fat, fluid	NZ FoodFiles
Gopala yoghurt	-	Yoghurt, plain, unsweetened	NZ FoodFiles
Green top milk	Generic- if no brand is available	Milk, cow, trim 0.5% fat, fluid	NZ FoodFiles
Light blue top milk	Generic- if no brand is available	Milk, cow, lite 1.5% fat, fluid	NZ FoodFiles
Margarine	If brand unspecified	Margarine, polyunsaturated, 70% fat, fortified	NZ FoodFiles
Salted butter	Generic- if no brand is available	Butter, salted	NZ FoodFiles
Skim milk powder	Generic	Milk, cow, powder, instant, skim	NZ FoodFiles
Yellow top milk	Generic- if no brand is available	Milk, cow, high calcium 0.1% fat, fluid, fortified	NZ FoodFiles
Yoghurt protein	Protein + yoghurt	Dairy Dream Hi-Protein Yoghurt Natural	AusBrands 2017
Eggs			
Eggs - poached	-	Eggs, chicken, white & yolk, poached	NZ FoodFiles
Meat and its alternatives			
Any meat/chicken/fish	If quantity not provided	100g as standard serve estimate[3]	-
Bacon hock	-	Courtway Smoked Hocks	AusBrands 2017
Chicken breast	Cooked, skin removed	Chicken, breast, flesh, roasted	NZ FoodFiles
Fats			
Chia seed	Generic	Seeds, chia, dried	AusFood 2017
Linseed	Generic	Seeds, linseed	AusFood 2017
Pumpkin seed	Generic	Seeds, pumpkin	AusFood 2017
Sesame seed	Generic	Seed, sesame	NZ FoodFiles
Sunflower seed	Generic	Seeds, sunflower	AusFood 2017
Drinks			
Black tea	Generic	Tea, black, regular, plain, without milk	NZ FoodFiles
Decaf coffee	Greggs Decaf	Nescafe Blend 43 Decaf	AusFood 2017
Earl Grey tea	-	Diplomat Earl Grey 50 Tea Bags	AusFood 2017
Espresso	Generic	Coffee beverage, espresso, café variety	NZ FoodFiles
Flat white	Small café style	Coffee beverage, flat white, double shot & milk standard 3.3% fat, 190mL, café variety	NZ FoodFiles

Food item	Example/brands/details	Correct substitution[1]	Database[2]
Drinks			
Flat white - trim	Small café style	Coffee beverage, flat white, double shot & milk trim 0.5% fat, 190mL, café variety	NZ FoodFiles
Green tea	-	Tea beverage, green	NZ FoodFiles
Instant & plunger coffee	-	Coffee, instant, dry powder	NZ FoodFiles
Water	-	Water, tap	NZ FoodFiles

[1] Default assumption selected from FoodWorks 9 Professional (version 9, 2018, Xyris Software); [2] Database used from FoodWorks 9 Professional (version 9, 2018, Xyris Software).